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Vol. XXXII, No. 4 APRIL, 1938 WHOLE NO. 273

SUNSPOT INFLUENCES *

By RALPH E. DE LURY

(*Annual Address of the President*)

SINCE the fluctuating meteorological elements exhibit responses to the sunspot cycle which vary in amplitude, phase and type in different geographical regions, as do weather variations associated with the yearly period, it follows that integrations of the meteorological conditions will reveal the sunspot influences typical of the region concerned, or blends of various kinds if considered over wide regions. Such integrations are involved in phenomena of lakes and rivers, in vital phenomena and in economics. The following examples illustrate various types of response to the solar variations.

THE SUNSPOT CYCLE AND ASSOCIATED ORGANIC AND ECONOMIC FLUCTUATIONS.

Lakes and Rivers — The variations of the Sun exert a profound influence on those of lakes and rivers and consequently on many forms of life and on economic conditions. Lake levels have been associated with the sunspot cycle by several investigators. Another interesting association of the cycle, important to navigation, is the variation in the times of freezing and break-up of ice in lakes and rivers. The sunspot relationship to the dates of freezing of Lake Monona,

*Continued from the March Number.

Wisconsin, has been noted by Wing[20]. Due to the sunspot influence on temperature, freezing occurs later about the years of minima than for the years about maxima, as shown in the following mean cycles:

Freezing of Lake Monona, 1851–1910, Days after October 31.

Year	0	1	2	3	4	5	6	7	8	9	10	11	Range
Mean	48.6	43.8	34.2	46.8	35.0	39.8	37.6	38.4	46.8	36.4	54.8	46.0	21
Smoothed	46.8	42.6	39.8	40.7	39.2	38.1	38.4	40.3	42.1	43.6	48.0	49.1	11

The ice conditions of the Great Lakes and the St. Lawrence River are probably similarly affected by the sunspot changes, introducing an important factor in the transportation of the United States and Canada.

A short record of the dates of "first ice" at Quebec and Montreal, 1910–1937, supplied by Chief Engineer J. E. St. Laurent of the River St. Lawrence Ship Channel Branch of the Department of Transport, exhibits an influence of the sunspot cycle similar to that of the freezing of Lake Monona, with an average range of 7 days as seen from the following smoothed mean December dates:

Year	0	1	2	3	4	5	6	7	8	9	10	11	Range
First Ice, December Dates, Quebec, 1910–1937	8.0	8.3	6.7	3.3	2.8	2.6	1.9	2.4	3.7	3.4	2.6	8.1	6.4
First Ice, December Dates, Montreal, 1911–1937	12.5	11.8	9.4	6.2	5.6	4.4	4.6	8.2	9.0	7.6	7.9	10.6	8.1
Mean, Quebec and Montreal	10.3	10.1	8.1	4.8	4.2	3.5	3.3	5.3	6.4	5.5	5.3	9.4	7.0

The variation in the discharge of the Niagara River has an important bearing on the development of electric power. As has been indicated there is a range of about 18,000 cubic feet per second in the mean of 6 cycles, with more than 10,000 in the range of the smoothed mean cycle. The sunspot cycle has a similar influence for each month, for the highest month and the lowest month in each year, and owing to the economic and political importance of the Niagara flow the various mean and smoothed mean cycles are given in Table VIII to the nearest integral number of thousands of cubic feet per second.

[20]Leonard William Wing, Trans. Second North American Wildlife Conference, 334, 1937.

TABLE VIII—Niagara River Discharge, Unit 1000 Cubic Feet per Second, Mean Cycle Followed by Smoothed Mean Cycle, 1860–1926.

Year 0	1	2	3	4	5	6	7	8	9	10	11	Range
						January						
196	193	188	183	201	198	203	202	195	194	195	184	20
193	193	188	189	196	200	202	201	197	194	192	190	14
						February						
189	183	182	179	191	189	195	194	187	188	184	176	15
184	184	182	183	187	191	193	192	189	187	183	181	11
						March						
195	189	195	186	203	197	201	196	196	203	194	185	17
191	193	192	193	197	199	199	197	198	199	196	190	9
						April						
203	198	196	200	211	200	211	206	204	212	198	197	16
200	199	197	202	206	206	207	207	206	206	201	199	10
						May						
212	210	203	211	225	211	223	218	218	223	209	206	21
210	209	207	212	218	218	219	219	219	218	212	208	12
						June						
216	215	206	218	230	218	226	221	220	224	212	207	24
214	213	211	218	224	223	223	222	221	220	213	210	14
						July						
215	215	207	217	229	217	223	219	219	219	212	205	22
212	213	212	217	223	222	221	220	219	217	212	209	14
						August						
208	208	203	211	223	214	217	217	212	213	206	203	20
207	207	206	212	218	217	217	216	214	211	207	205	13
						September						
203	203	201	206	218	212	212	211	209	210	204	201	18
202	202	203	208	214	214	212	211	210	208	205	202	12
						October						
199	200	196	204	212	209	207	206	203	205	201	195	15
198	199	199	204	209	209	207	206	204	203	201	197	12
						November						
197	200	195	204	212	211	207	206	201	205	206	199	17
198	198	199	204	210	210	208	205	203	204	204	200	12
						December						
199	197	194	201	207	208	207	205	206	201	206	196	15
198	196	196	200	206	208	207	206	204	203	202	199	11
						All Months						
203	201	197	202	214	207	211	209	206	208	202	196	16
201	200	199	204	209	210	209	209	207	206	202	199	10
						Seven Months, April to October						
208	207	205	210	221	212	217	214	211	215	206	202	19
206	207	207	211	216	215	215	214	213	211	207	204	12
						Highest Month, Each Year						
218	218	210	221	232	219	226	222	221	224	214	207	22
215	216	215	221	226	224	223	223	222	221	215	211	15
						Lowest Month, Each Year						
188	182	181	179	190	189	195	188	187	187	185	176	16
184	183	180	182	187	191	191	189	187	187	183	181	11
						Highest Month Minus Lowest Month, Each Year						
29	36	29	43	42	31	31	34	34	37	29	30	
31	33	35	39	39	33	32	33	35	34	31	30	
						Mean Sunspot Cycle						
5	14	43	72	87	76	63	45	31	19	11	7	
Year 0	1	2	3	4	5	6	7	8	9	10	11	

Floods cause an appalling destruction of various forms of life and property. Annually in the United States nearly 100 people lose their lives due to floods and about $50,000,000 in loss of property is suffered[21]. The sunspot cycle through its influence on precipitation, cloudiness and temperature is undoubtedly a factor in this destruction. The following mean cycles in the average precipitation of the Upper Mississippi Basin derived from the determinations by Hoyt and others as quoted by Wing (p. 365)[20], show peak precipitation in the third year of the cycle, and it is possibly of significance that the three disastrous Mississippi floods in 1903, 1927 and 1936 were closely associated with this peak, occurring in the second, third and fourth years of the cycle.

Precipitation in Inches, Upper Mississippi Basin, 1878–1934.

Year	0	1	2	3	4	5	6	7	8	9	10	11
Mean	26.2	30.7	31.2	33.6	29.8	29.7	29.2	29.3	29.0	25.6	30.8	30.3
Smoothed	28.4	29.8	31.7	32.0	30.7	29.6	29.4	29.2	28.2	27.8	29.4	29.4

Trees—Measurements of the annual rings of trees have provided a powerful means of investigating climatic cycles. The extensive work of A. E. Douglass has revealed certain climatic factors among which the sunspot cycle is prominent, the type of response varying in different regions as in the case of the weather cycles. His chart of the average growth of 57 North European trees which fluctuates with remarkable fidelity with the sunspot changes showing an average range in the annual rings of 20 per cent. in the mean sunspot cycle, should be examined by those who are still doubtful concerning the profound influence of the solar variations on terrestrial affairs[22]. His measurements of old trees in the southwestern United States in comparison with those of timbers used in old buildings recently unearthed have thrown an interesting sidelight on the history of the early peoples of the region. The measurements of the giant redwoods have indicated the influence of the sunspot cycle back more than 3,000 years, besides providing a rich store of material for comparison with other phenomena of the past.

The writer derived the smoothed mean cycle in annual rings of the redwoods for comparison with other phenomena[1] and the sunspot cycle for the interval 1784–1869 (Table IV). The maximum

[21]J. B. Kincer, Bull. American Meteorological Society, 18, 306, 1937.

[22]A. E. Douglass, Climatic Cycles and Tree-Growth, Carnegie Institution of Washington, Publication No. 289, p. 77, 1919.

in the smoothed cycle, 0.915 mm., exceeds the mean of the other values in the cycle, 0.875 mm., by 0.040 mm. It is interesting to note that the mean of the widths of the annual rings for the 70 years of the Chinese records of sunspots exceeds the mean of the means for the decades in which the spots were observed by 0.029 mm., which is in harmony with the idea that the records were made near the years of sunspot maxima. From the Chinese records it appeared that a maximum of sunspots was near 1066 when Halley's comet was such a brilliant object. The smoothed mean of five cycles of 11 years, each in the growth-rings of the redwoods, assuming 1060 to be a minimum year, is as follows:

0	1	2	3	4	5	6	7	8	9	10
.94	1.00	1.03	1.05	1.07	1.07	1.06	1.07	1.04	.97	.91

This indicates that the comet of 1066 occurred probably a year after a sunspot maximum, and was consequently abnormally bright due to the extra emission of ultra-violet light from the sun, in harmony with the behaviour of Encke's comet. This deduction is, of course, based on the assumption that the growth of the redwoods is in positive phase with the sunspot cycle as indicated by the smoothed cycle for the interval, 1784–1869.

Our first measurement of a tree-section was that of an extremely interesting pre-glacial Sitka spruce presented to us by Chief Engineer K. M. Cameron of the Public Works Department, and collected by District Engineer A. P. Forde shortly after its release from the retreating glacier in Tarr Inlet, northwestern British Columbia[23]. A smoothed mean of ten 11.5 year cycles was derived from the mean of the mean cycles of measurements along five radii. The section was small and had to be boiled in paraffin to reinforce it sufficiently to be turned smooth in a lathe to make suitable photographs possible. Each measurement showed strong evidence of the influence of the sunspot cycle, operating in the remote past before the oncoming glacier buried the tree. This extended the evidence of the existence of sunspots farther back than had previously been known. It was desirable to get another and a larger specimen, and this was kindly done by Mr. Forde. The second section was measured and analysed by Mr. John L. O'Connor.

[23]Jour. R.A.S.C., 21, 274, 1927.

The smoothed mean cycles of the two specimens are as follows, with the years approximately in positive phase, as derived from the measurements of living trees in the general region:

Two Pre-glacial Sitka Spruce Trees, Released from the Glacier, Tarr Inlet, Northwestern British Columbia, 115 and 243 Years.

Year? 0	1	2	3	4	5	6	7	8	9	10	11	Range %
.496	.509	.527	.556	.582	.580	.543	.522	.506	.499	.492	.489	19
.99	1.04	1.07	1.09	1.09	1.08	1.08	1.09	1.09	1.04	.99	.97	12

TABLE IX.—Trees, Various Regions in Canada, 1617–1931, Smoothed Mean Eleven-Year Cycles, Annual Growth of Rings in mm.

Year 0	1	2	3	4	5	6	7	8	9	10	11	Range %
22 Borings, Pine and Spruce, University Forest, Frederickton, New Brunswick, 1870–1930.												
2.37	2.45	2.48	2.38	2.23	2.10	2.02	2.00	2.15	2.32	2.33	2.30	24
4 Sections, Spruce, Matamek River, Quebec, 1784–1930												
1.21	1.23	1.26	1.26	1.20	1.18	1.23	1.27	1.28	1.32	1.32	1.24	12
2 Sections, Spruce, Pentacost River, Quebec, 1842–1929.												
2.32	2.13	2.02	1.92	1.83	1.85	1.89	1.94	2.07	2.18	2.28	2.40	31
1 Section, Pine, St. Maurice River, Quebec, 1617–1929.												
.97	.91	.88	.86	.86	.87	.84	.85	.87	.87	.94	1.01	24
1 Section, Willow, Baffin Island, 1900–1930.												
.723	.742	.813	.813	.821	.890	.899	.865	.856	.871	.893	.823	24
2 Sections, Beech and Maple, Manilla, Ontario, 1741–1931.												
1.26	1.31	1.33	1.36	1.40	1.41	1.35	1.31	1.37	1.42	1.35	1.25	13
7 Sections, Spruce and Pine, 40 Miles S.E. of Winnipeg, Manitoba, 1826–1930.												
2.31	2.40	2.41	2.32	2.15	1.99	1.94	1.99	1.99	2.10	2.28	2.29	24
14 Sections, Spruce and Balsam Fir, near Powell, Manitoba-Saskatchewan, 1800–1930.												
1.88	1.89	1.91	1.93	1.91	1.82	1.72	1.74	1.81	1.89	1.95	1.93	12
1 Radius, Spruce, Red Rock Lake, Coppermine River, N. W. T., 1749–1930.												
.469	.481	.481	.461	.439	.441	.448	.447	.443	.444	.455	.459	9
6 Sections, Cedar, Fir and Hemlock, New Westminster, British Columbia, 1749–1930.												
.82	.86	.89	.90	.93	.94	.93	.91	.86	.80	.79	.80	19
2 Sections, Spruce, Delta of the Mackenzie River, N. W. T., 1667–1930.												
1.05	1.09	1.08	1.06	1.07	1.08	1.09	1.09	1.07	1.04	1.02	1.01	8
Mean Sunspot Cycle, 1749–1936.												
6	15	45	77	84	78	67	50	36	25	18	10	
Year 0	1	2	3	4	5	6	7	8	9	10	11	

The second and larger tree (243 years) evidently grew under more favorable conditions than the smaller, and it shows a smaller range of variation in the eleven-year cycle. It resembles in the cycle range the growth of two spruce from the Delta of the Mackenzie River (Table IX), which grew in low-lying silt on the banks of a creek connecting two lakes. The age of these specimens must

be a matter of great uncertainty; but some geologists suppose that the trees probably grew 300,000 years ago. The glacier in the region has been in progressive retreat since its front was noted by Vancouver nearly a century and a half ago. It seems reasonable to suppose that this retreat is the continuation of the withdrawal of the glacier which left Ontario some 30,000 years ago, and that the trees were imprisoned during the occupation of the continent by the glacier. This would surely mean that the trees are several hundred thousand years old. It would seem, therefore, that the sunspot cycle is old and established, and that its causes are to be found in variables of astronomical constancy such as the orbital motions of the planets. Such clues are of value in the solution of the problem of the causes of sunspots. A corollary to the investigation of the pre-glacial spruces is the study of the old Sitka spruces occupying the territory today.

To extend our knowledge of the influence of the sunspot cycle and other astronomical factors to years and regions not covered by the meteorological records of Canada, the measurement of tree-growths was undertaken at the Dominion Observatory. Tree-sections were secured from various regions across the populated belt of Canada, especially for comparison with the meteorological records; but specimens were even more desired from the northern parts of the continent, and a few of them have been obtained. We are happy to acknowledge the co-operation of federal and provincial officers, of the late R.C.M.P. Commissioners Cortlandt Starnes and Sir James H. MacBrien and their outpost officers and of naturalists who have kindly supplied us with tree specimens. The tree-sections have preferably been turned in the lathe, photographed and positive copies of selected radii measured on the 300 mm. micrometers of the observatory. This immense amount of work and the analysis of the measurements have been performed by Mr. John L. O'Connor. Smoothed mean cycles of trees and groups of trees are given in mm. in Table IX, for different regions of Canada. It is of interest to inspect the types of response to the sunspot cycle in the various geographical regions.

The cycle in the growths of trees in British Columbia, from near New Westminster, appear to be in positive phase with the

sunspot cycle (Oceanic or Aquene type). Those from the Pentecost River, and the pine from the St. Maurice River, Quebec, show the negative phase (Inland or Terrene type). The smoothed mean

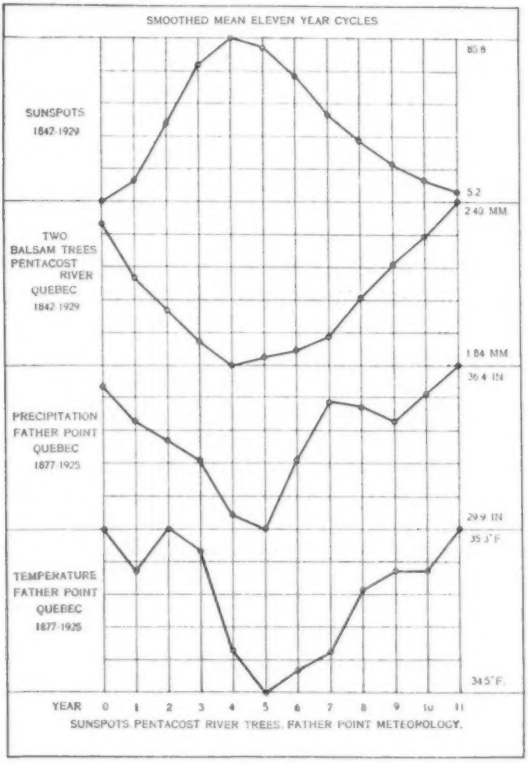

Fig. 8

cycle of the Pentecost River trees is charted in Fig. 8, along with the cycle in precipitation and temperature of the short meteorological record of Father Point (See also the Montreal cycle of precipitation in Fig. 6). The trees from Matamek River, Quebec, are of the two-pulse type in the cycle, similar to the precipitation type

of Southwest Pt., Anticosti, both being charted in Figure 9. The willow from Baffin Island may be regarded as of positive phase delayed two years. The trees of Manilla, Ontario, exhibit the

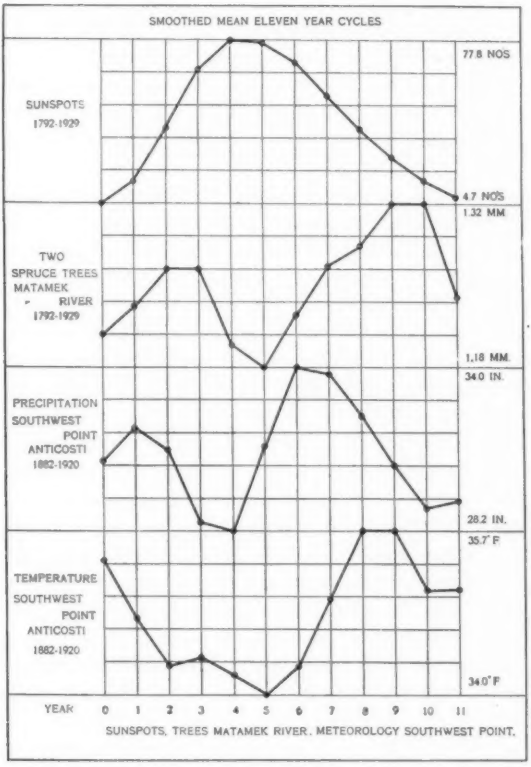

Fig. 9

positive phase with a slight depression after maximum, a type often seen in precipitation cycles. The trees of the Mackenzie River Delta show a type a year or two in advance of direct or positive phase. The New Brunswick, Manitoba, Saskatchewan and Coppermine River trees exhibit the inverse phase delayed a year or two, similar

in this respect to the precipitation cycle in the Upper Mississippi River Basin previously mentioned. (Compare this with the grouse cycle in Manitoba, Fig. 11.)

The preliminary survey of tree-growths in Canada points to the need of a widespread investigation of well-selected old trees from all parts of Canada, and especially from the northern regions.

Farm Crops—Early attempts to detect a possible influence of the sunspot cycle on yields of grains failed probably from lack of knowledge of the different types of meteorological response to the cycle in various geographical regions. The characteristics of each region should when possible be considered separately. To illustrate, one might erroneously conclude that the sunspot cycle exerts no influence on precipitation, by averaging aquene and terrene types of cycle of opposite phase. Or again, one could draw the false conclusion that there was no influence of the yearly period on precipitation by averaging such well-defined yearly types as the winter type of St. John's, Newfoundland, with the summer types of the prairie province stations.

The regional records of grain yields in Canada should be examined in relation to the sunspot changes; but as these were not available the Canadian records for two sunspot cycles, 1908–1929, were inspected with the expectation of finding evidence of the predominating influence of the inverse type of the prairies in temperature and precipitation. Such is seen to be the case in the mean cycles of the grains given in Table X, along with other crops. Each of the individual grains shows greater yields in the years about sunspot minima, in harmony with the higher temperature and precipitation at minima of spots. The smoothed mean cycle of the four grains, wheat, oats, barley and rye, shows a range of 7.2 bushels to the acre or of 36 per cent. Obviously, however, not much reliance can be placed on this range, as a much longer record of yield is necessary to deduce the average influence of the sunspot cycle. It may be pointed out that the favourable meteorological influences associated on the average with sunspot minimum conditions, may at times be considerably offset by unfavourable distribution of the showers of rain, and also by grasshoppers which appear to be more prevalent about the years of few sunspots (See Fig. 11). The smoothed mean cycle of the four grains is charted in

Fig. 10, along with that of potatoes and the value of fisheries. The potato yield appears to have a double pulse, possibly associated with such a type in meteorology in the eastern provinces, and

TABLE X.—Mean Cycles in Sunspots and Canadian Farm Crops, 1908–1929; and Value of Canadian Fisheries, 1870–1917.

Year 0	1	2	3	4	5	6	7	8	9	10	1111
Sunspots, Mean Cycle											
4	13	46	61	87	79	64	43	35	16	66	4
Wheat, Bushels per Acre, Mean Cycle											
21.4	13.9	22.5	17.4	18.6	17.3	11.0	15.8	17.3	16.4	20.8	20.5
Oats, Bushels per Acre, Mean Cycle											
39.1	29.7	36.2	33.7	31.8	31.6	24.5	32.7	31.7	31.1	38.0	39.3
Barley, Bushels per Acre, Mean Cycle											
28.9	25.2	28.1	25.6	25.4	26.2	19.3	25.8	25.6	25.7	29.3	31.3
Rye, Bushels per Acre, Mean Cycle											
17.7	16.7	17.4	17.9	19.2	16.4	13.4	17.3	15.3	14.5	19.0	19.0
Buckwheat, Bushels per Acre, Mean Cycle											
22.5	25.1	22.6	19.6	20.6	21.2	21.9	24.2	25.3	21.2	22.8	26.5
Flaxseed, Bushels per Acre, Mean Cycle											
11.3	7.2	10.4	10.3	8.4	7.7	5.2	8.2	11.9	8.1	11.5	13.0
Wheat, Oats, Barley and Rye, Mean											
Mean Cycle											
26.8	21.4	26.1	23.7	23.8	22.9	17.1	22.9	22.5	21.9	26.8	27.5
Smoothed Mean Cycle											
25.6	23.9	24.3	24.3	23.6	21.7	20.0	21.4	22.5	23.3	25.8	27.2
Potatoes, 100 Pounds per Acre											
Mean Cycle											
99.3	104.5	75.8	85.1	77.1	84.5	82.7	90.8	103.8	76.6	89.3	105.3
Smoothed Mean Cycle											
102.1	96.1	85.3	80.8	80.8	82.2	85.2	92.0	93.8	86.6	90.1	99.8
Value of Fisheries, Year Ending June 30, Unit $1,000,000.											
Mean Cycle											
22.5	21.6	22.0	20.1	22.8	18.4	18.7	18.6	19.4	19.7	20.3	21.6
Smoothed Mean Cycle											
22.1	21.9	21.4	21.3	21.0	19.6	18.6	18.8	19.3	19.8	20.5	21.5
Year 0	1	2	3	4	5	6	7	8	9	10	11

obviously the provincial yields should be considered separately. While the fish have fluctuations of their own, it is likely that the value is associated with the agricultural yields. Such as it is, the cycle parallels the grain cycle.

In the United States wheat is grown in regions exhibiting different responses to the sunspot cycle in meteorology and tree-

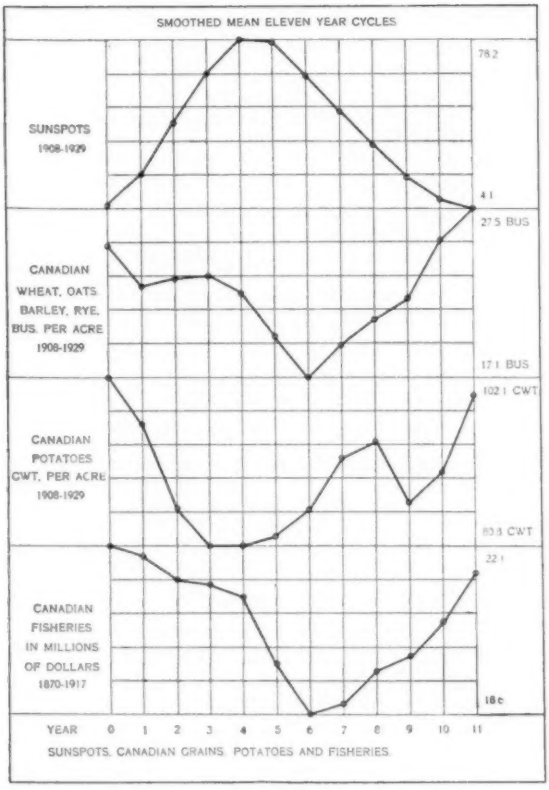
SMOOTHED MEAN ELEVEN YEAR CYCLES
SUNSPOTS 1908-1929
78.2
4.1
CANADIAN WHEAT, OATS, BARLEY, RYE, BUS. PER ACRE 1908-1929
27.5 BUS
17.1 BUS
CANADIAN POTATOES CWT. PER ACRE 1908-1929
102.1 CWT
83.3 CWT
CANADIAN FISHERIES IN MILLIONS OF DOLLARS 1870-1917
22.1
18c
YEAR 0 1 2 3 4 5 6 7 8 9 10 11
SUNSPOTS, CANADIAN GRAINS, POTATOES AND FISHERIES

Fig. 10

growths (Douglass), and consequently it is not surprising to find very little influence of the sunspot cycle in the wheat yields of the whole country, as follows:

Wheat, United States of America, 1867–1910, Bushels per Acre.

Year	0	1	2	3	4	5	6	7	8	9	10	11
Mean	13.2	12.9	13.7	12.1	12.8	13.1	13.4	12.3	13.2	13.0	12.4	12.3
Smoothed	12.9	13.2	13.1	12.7	12.7	13.1	13.1	12.8	12.9	12.9	12.5	12.6

However, an inspection of a short record of yields in Montana and the Dakotas indicates that the inverse type similar to that of the Canadian prairies is present in that general region. In the yield of corn in Iowa, 1871–1924, Wylie has found the inverse type in the sunspot influence[24]. The cotton yield in the United States, restricted to a narrower region than that of wheat-growing, exhibits a definite influence of the sunspot cycle, as follows:

Cotton, United States of America, 1867–1910, Pounds per Acre.

Year 0	1	2	3	4	5	6	7	8	9	10	Range
Mean 182	187	184	190	167	187	167	157	175	185	180	33
Smoothed 183	185	186	183	178	177	169	164	173	181	182	22

The range is about 13 per cent, and the type of fluctuation is curiously similar to that of the precipitation in the Upper Mississippi Basin, previously noted.

Statistics of wheat prices, discussed by W. S. Jevons and W. H. Beveridge, exhibit on analysis the two-pulse type common to the meteorology and life phenomena of the British Isles, mean cycles of which are given in Table XI.

Diseases—It is probably safe to state that all diseases of plants and animals are affected by the weather conditions, and in consequence their variations are associated with the sunspot cycle. It is probable also that all organisms are affected, favourably or unfavourably, by ultra-violet light. The amount of this reaching the surface of the earth varies with the sunspot cycle (Pettit) due in part to its emission from the sun which varies in positive phase with the sunspot cycle and in part to the transmission of the upper terrestrial atmosphere which varies in negative phase with the sunspot cycle. Tthe action of ultra-violet light induces the production of ozone and other compounds as well as haziness and cloudiness, which in turn exert an impedance to ultra-violet light relative to that for other wave-lengths of light.

In general, diseases show marked seasonal variation in harmony with the weather variations in the annual period, and since these variations are seriously affected by the sunspot variations it follows

[24]C. C. Wylie, Popular Astronomy, 35, 253–6, 1927.

that the diseases will show regional types of response to the sunspot cycle. It is well known that typhoid fever and certain oriental diseases are closely associated with rainfall. Respiratory diseases are sensitive to certain types of weather. Long records of such diseases would doubtless reflect the regional type of sunspot cycle in precipitation. The charts of various diseases given by White for short intervals are tantalizing in their suggestiveness of the influence of the sunspot cycle.[25] The number of cases of poliomyelitis in 38 states of the United States in 1927 was approximately three times greater than the average number for the preceding years back to the minimum of spots in 1923. Perhaps it is merely a coincidence that the epidemic of this disease of last year in Ontario and other regions occurred at a maximum of sunspots. Coinciding with the spectacular peak in sunspots at the maximum in 1917.6, meningitis surged to abnormal peaks in 1917 and 1918, subsiding to lows in 1922–1925 and rising steadily to a lesser peak in 1928 at the time of a smaller maximum of sunspots. Mortality in 24 states due to pulmonary tuberculosis decreased progressively from 1917 and 1918 by approximately 30 per cent to 1921. The great influenza epidemic of 1917 and 1918 also coincided with the large peak in sunspots. If, as seems likely, the sunspot cycle is a factor in the variations in influenza, the contention of the astrologers that it was due to the *influence* of the planets can be condoned since the period is near that of the planet Jupiter and that of the 10-year interval between oppositions and conjunctions of that planet with Saturn, both of which may indeed be factors in the causes of sunspots. The dates of epidemics of influenza in the British Isles, 1676–1907, arranged in the years of the sunspot cycle, as well as the mortality due to influenza in London, 1847–1907, appear to show the double pulse type of response to the sunspot cycle typical of the British Isles, in precipitation and other phenomena (Table XI). Insects transmit diseases to other forms of life, thus adding another variable to be considered in relation to the direct and indirect influence of the solar variations.

Insects, Birds and Animals—Long homogeneous records of wildlife are rare, unfortunately. The Chandon dates of arrival of

[25]William Charles White, Second Conference on Cycles (Washington), 42, 1929.

the cuckoo, lark and swallow, 1784–1869, exhibit fluctuations with the sunspot cycle[26], the mean cycle of the three birds exhibits a smoothed amplitude of 4 days, in positive phase with the sunspot

TABLE XI.—Phenomena of the British Isles, Smoothed Mean Cycles.

Year 0	1	2	3	4	5	6	7	8	9	10	11
Precipitation, Inches, Aberdeen, 1871–1909											
30.2	30.2	30.5	29.7	30.7	32.3	31.2	29.9	30.4	31.4	32.8	32.3
Precipitation, Inches, Edinburgh, 1856–1912											
27.1	25.9	25.5	25.4	26.9	28.8	27.7	25.0	24.9	26.3	27.9	28.5
Precipitation, Inches, Glasgow, 1868–1909											
37.4	37.2	38.8	37.2	38.8	42.0	40.3	36.7	36.4	38.6	41.9	41.9
Wheat Prices Comparative to 40 Commodities (W. S. Jevons), 1784–1864											
130	129	131	131	131	134	139	137	129	126	127	130
Corn: (Wheat, Barley, Oats, Rye, Beans and Peas), Actual Prices (W. S. Jevons), 1784–1864											
136	142	153	152	138	128	130	137	138	140	146	144
Wheat, Index of Fluctuation (W. H. Beveridge), 1784–1869											
94	91	96	101	103	103	100	96	94	96	103	103
Influenza, Number of Epidemics in the Various Years of the Cycle, London, 1676–1907											
3	1	2	2	3	3	2	2	2	3	3	(1)
Influenza, Deaths per Million People, London, 1847–1907											
114	106	129	163	153	148	121	80	72	89	138	166
Nightingale, April Dates of First Song, Marsham Records, 1739–1915											
24.9	24.7	26.3	28.1	28.1	26.5	26.1	27.0	26.9	26.1	25.9	25.8
Grouse, Kill on Scotch Moors, 1858–1909											
83	74	69	81	112	119	101	95	105	124	136	112
Red Grouse, Disease, 1872–1909											
23	27	30	22	13	22	39	37	25	20	14	15
Marriages, per 10,000 People, England and Wales, 1860–1913											
78.4	78.0	77.9	78.4	79.4	80.1	79.9	79.5	79.3	79.6	79.5	79.0
Marriages, per 10,000 People, Scotland, 1867–1912											
69.0	68.2	69.1	70.0	70.3	71.0	70.8	69.4	68.7	69.2	69.9	70.0
Marriages, per 10,000 People, Ireland, 1864–1913											
49.5	48.1	47.6	48.4	48.8	48.6	48.6	48.3	48.4	49.2	49.8	50.1
Sunspot Relative Numbers, 1856–1922											
Mean 4	15	45	77	87	76	63	45	31	19	11	7
Smoothed 7	19	45	71	81	75	62	46	32	20	12	7
Year 0	1	2	3	4	5	6	7	8	9	10	11

cycle and paralleling the precipitation cycle[1] (See preceding Table IV), at Montdidier, France. In England, 118 records of the first song of the nightingale, 1739–1915 (Marsham Records), show an

[26]The Auk, 40, 414–9, 1923.

amplitude of 3 days in the smoothed mean cycle, with a slight secondary pulse typical of the British Isles (Table XI). The influence of the sunspot cycle on dates of arrival of birds in the United States has been found by Wing and others.

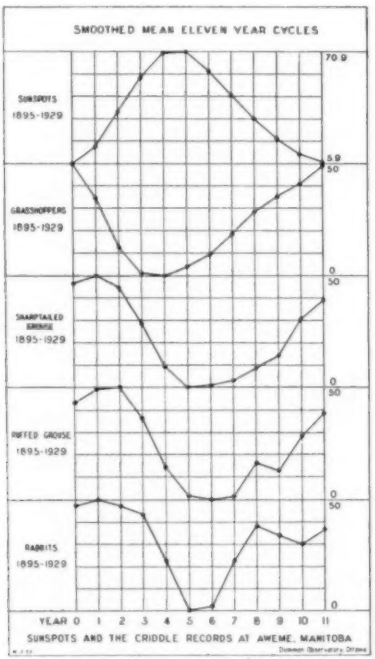

Fig. 11

The Criddle records of abundance of grasshoppers, ruffed grouse and sharptailed grouse kept at Aweme, Manitoba, 1895–1929,[27] exhibit the influence of the sunspot cycle.[28] In Fig. 11 are charted their smoothed mean cycles, along with that of the rabbit record which was privately communicated. The type of the grouse

[27]Norman Criddle, Can. Field-Naturalist, 44, 77, 1930.

[28]Can. Field-Naturalist, 44, 120, 1930.

mean cycle is similar to that of the Manitoba tree-growth cycle (Table IX), in harmony with the temperature and precipitation cycles. In Fig. 12 the cycles are inverted and grouped in phase

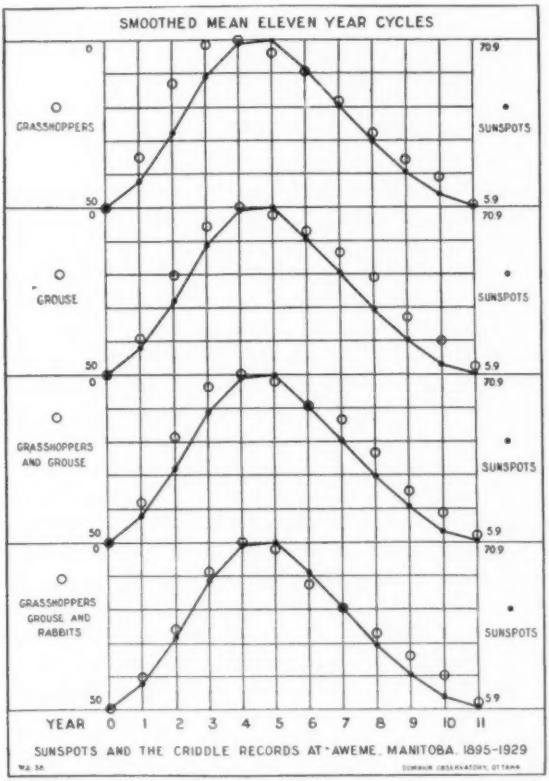

Fig. 12

with the sunspot cycle. In Manitoba, about sunspot minimum, the conditions are favourable to all these forms of life.

At the Matamek conference, Leopold presented a comparison of the American grouse cycles with the shorter British cycles. The

present writer suggested that the shorter British cycle was probably related to the two pulses of precipitation in the British Isles in the sunspot cycle like that at Anticosti, of the terraquene type. The grouse charts have since been published,[29] as percentage departures from average, and from these charts the mean double pulse cycles have been deduced (Table XI), and these mean cycles are shown in comparison with precipitation cycles in Scotland in Fig. 13. Thus it would seem that the grouse follow the type of the meteorological response to the sunspot cycle in the region concerned, in so far as the sunspot factor is concerned.

The Criddle records show the prevalence of grasshoppers about the years of sunspot minima. It is of interest to recall that tent-caterpillars in the sunspot minimum years, 1913 and 1923, caused locomotives to skid to a stop on the railway north of Ottawa, in Quebec; and a similar happening occurred near Sudbury at the last sunspot minimum. The spruce budworm was prevalent in certain regions in 1878 and 1913, possibly in association with sunspot minima of those years. The work of Gross on the parasites of grouse; that of Green on the tick influence on rabbit fluctuations; and similar work by many others points to the great need of records of abundance of insects, a factor which has been neglected by the biologists, no doubt due to the difficulty of making the records.

The fur records of the Hudson's Bay Company exhibit fluctuations of irregular extent and duration with average periods for the different animals of about 10 years or less. The writer suggested that the sunspot cycle was an important factor in these variations[30]. In a contribution on "Astronomical Cycles, the Weather and Life" at the Matamek conference in August, 1932, he suggested that the periodical fluctuation resulted from a blending of the sunspot influence of 11.2 years and the lunar periods of 18.6 and 8.85 years which latter combine in a 9-year period of varying amplitude. A fair reproduction of the black fox fluctuation resulting from such blending was exhibited. The two lunar periods appear to be present in tree-growth measurements and meteorological phenomena. At the conference Huntington showed the apparent influence of the longer cycle on economic fluctuations. The fur records are of course a blend from various regions where the types

[29]Aldo Leopold and John N. Ball, Can. Field-Naturalist, 45, 162–7, 1931.

[30]Pub. American Astronomical Society, 6, 101, 1927.

of response to the astronomical cycles are not the same. Future records should be regional.

Economic Fluctuations—With such profound influences of the sunspot cycle in physical and organic phenomena it follows that

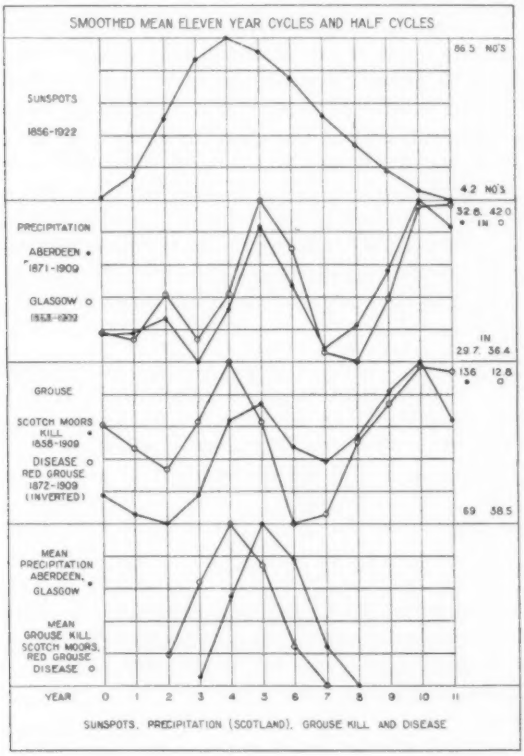

Fig. 13

economic conditions must also be affected by the solar variations. The commodity prices in Great Britain and Ireland exhibit for the interval 1784–1869, a response to the sunspot cycle in inverse phase and with a lag of a year[1] (Table IV). Wheat prices and

statistics exhibit the double pulse type of cycle of the British Isles (Table XI).

Economic fluctuations must surely be a factor in variations of marriage-rates; and consequently it is not surprising to find in these variations the apparent influence of the sunspot cycle. From the records assembled by Knibbs[31] the mean cycles for the marriage-rates of England and Wales, Scotland and Ireland were deduced and are given in Table XI. They too reflect the double pulse type of cycle characteristic of that region. The mean cycle for 15 countries (Australia and 14 European countries) exhibits a positive phase with a lag of 3 years, and a slight secondary pulse due to the terraquene influence chiefly of the British Isles. The record for France is similar to that of the mean of the 15 countries, and is almost identical with the mean cycle for comparative wheat prices (compared with 40 commodities, Table XI). The mean cycle in the marriage-rates of Austria is in perfect positive phase with the sunspot cycle, as follows:

Marriage-Rates in 15 Countries, France and Austria, 1867–1912, Smoothed Mean Cycles, per 10,000 Population.

Year 0	1	2	3	4	5	6	7	8	9	10	11
Fifteen Countries											
74.0	73.4	72.9	73.0	73.6	74.2	75.4	75.1	74.6	74.2	73.9	74.3
France											
76.3	75.9	76.4	76.3	77.2	79.2	79.5	78.9	77.8	76.9	77.0	77.3
Austria											
78.5	80.3	83.1	83.8	83.5	83.1	83.0	82.3	80.9	79.5	78.8	77.8

The long period of 60 to 70 years, exhibited as a surge in the amplitude of the 11-year cycles, is apparently reflected in positive phase, in births, deaths and marriages in Russia, 1800–1900, and in Leningrad, 1760–1900, according to the findings of G. I. Pokrowski[32].

An interesting association of the sunspot cycle with the total production (exclusive of crops) in the United States, 1876–1929, has been deduced by Garcia-Mata and Shaffner[33]. The peaks of

[31]G. H. Knibbs, The Mathematical Theory of Population, 178.

[32]G. I. Pokrowski, Science, 67, 397, 1928.

[33]Carlos Garcia-Mata and Felix I. Shaffner, Quarterly Journal of Economics, 49, 20, 1934.

the production chart occur 2 or 3 years after sunspot minima, and consequently the chart they have derived of the rate of change in the sunspot cycle parallels the production chart fairly closely. From the production chart, expressed in percentage departures from normal or average, the following mean and smoothed mean cycles, expressed in positive departures above the greatest negative departure, have been deduced:

Production, Exclusive of Crops, United States, 1876–1929, Percentage of Normal, Above Low.

Year 0	1	2	3	4	5	6	7	8	9	10	11
Mean 3.5	5.0	5.3	5.8	5.1	2.3	.1	.0	.0	.5	1.6	1.6
Smoothed 3.4	4.7	5.4	5.5	4.6	2.5	.6	.0	.1	.7	1.3	2.1

These mean cycles show the same phase relationship to the sunspot cycle as exhibited by the precipitation cycle in the Upper Mississippi Basin, 1878–1934, and the cotton yield cycle, 1867–1910, previously mentioned.

We have drawn, I trust, a fair and consistent picture of the influence of the sunspot cycle on a number of physical, organic and economic variables. Many in Canada are becoming interested in the subject; notable investigations of the sunspot influence particularly on western meteorology have been made by F. Napier Denison and W. A. Thorn. Such investigations with longer records in many fields will make of the sunspot cycle a valuable factor in forecasting some years in advance. Forecasting any variable for a year or more in advance without recognition of the sunspot influence would be as inadequate as forecasting a variable a month or more ahead without the knowledge of the mean yearly cycle of this variable. Neglecting the daily and yearly periods, the only other astronomical periods, in addition to the solar periods, which have been suggested with any show of reason are the lunar periods. Tides and tidal currents undoubtedly affect our climate, and possibly those occurring in the atmosphere are of more importance than those in the waters. It is believed that the periodic changes in our climate are functions of the solar periods and the lunar periods in position and velocity of transfer of the earth-moon line on the surface of the earth coupled with the variations of the tidal force in monthly, 8.85 and 18.6 year periods, the blending of the periodic effects varying in phase and type with geographical region.

In addition to these fundamental periods, secondary or spurious periods such as the Brückner cycle, of from 22 to 55 years, will result. These will appear and disappear depending on fortuitous regional blending. The periods of about 35 and 55 years will be frequently present.

In addition to periodic effects there are undoubtedly great influences of terrestrial happenings such as the presence of volcanic ash in the atmosphere for years at a time, and the slow retreat of the glaciers producing an upward trend in temperature (possibly causing the trend in the prairie temperature found by T. C. Main and others). The writer called attention to the synchronization of the 260-year fluctuation in the moon's longitude, with a similar fluctuation in annual rings of the California redwoods and the "break" in meteorology which occurred about 1840 and was reflected in the profound increase in precipitation at Upsala[34]. Later, H. H. Turner derived the same period from the same measurements of the redwoods (in Huntington's *The Climatic Factor*). The measurements of the redwoods made by Douglass do not support the idea of the periodicity of 260 years. However, two old Manilla, Ontario, trees show a great increase in growth which commenced about 1840 and was maintained till after the end of the century. Possibly the fluctuation is not periodic. It is not known for certain that the longitude fluctuation of the moon is periodic. It is conceivable that due to the rising of the ice over polar seas, or due to an earthquake before the middle of the last century, a wider channel for the flow of Pacific waters through the polar regions and down to the Atlantic was created rather suddenly, thus accounting for the profound change in meteorology; and by the slowing of the rotation of the earth, caused by the melting of much polar ice, the moon would gradually get ahead of its computed position based on the assumption that the earth was a constant time-keeper.

Investigators of the various climatic factors are busy all over the world and we hope for speedy and valuable results in the matter of long-range forecasting.

Dominion Observatory, Ottawa, Canada.

[34]Pub. Am. Astron. Soc., 4, 214, 1920.

Errata in March number: p. 108, Table 1 for % read $\pm$; p. 115, 3rd line from bottom, for H read H α; p. 116, line 13, for *hour* read *second*; p. 128, line 23, entry for 1883, for *5* read *32*.

THE PROBABLE EXISTENCE OF AN AREA OF MAXIMUM ACTIVITY ON THE SUN*

By I. L. THOMSEN

During the course of the year 1937, the appearance of sunspot groups in certain areas of the sun attracted the writer's attention, and his feeling grew to conviction, that there was a zone on the sun, centred at about 180° solar longitude, in which activity was greater than in other longitudes. To show definitely that such might be the case is not easy, without going into lengthy discussions on the detailed histories of many sunspot groups; but the following rough analyses of the observations made at Wellington help in showing that such a phenomenon may have had a real existence.

From the observations it is possible to select immediately by inspection, the largest and most active sunspot groups observed during the year as follows:

Wellington Serial No. of Group.	G.M.T. Date of C.M. Passage. 1937	Heliographic Latitude	Heliographic Longitude
4	Jan. 24.0	−18°	293°
11	Jan. 30.2	+19	206
12*	Jan. 31.0	−12	197
13	Jan. 31.2	−22	192
6b	Feb. 22.9	+20	252
44*	Mar. 1.9	+ 6	161
67*	Apr. 23.1	+22	193
68*	Apr. 24.5	+17	174
72	Apr. 29.5	−19	110
82	May 20.9	−16	191
85	May 27.1	+10	106
97	Jun. 15.6	+10	207
102	Jun. 27.1	−13	53
115*	Jul. 28.5	+30	359
136	Sep. 9.8	+12	147
141	Sep. 11.0	+10	130
157*	Oct. 4.5	+ 8	181
220	Dec. 20.1	+21	249

*Sent for publication by R. C. Hayes, Acting Director of the Dominion Observatory, Wellington, N.Z.

The large group which was on the central meridian on 1938 January 18.5d in latitude +15°, longitude 224°, and had a strong resemblance in characteristics to no. 157 above, might also be considered in conjunction with this table. Groups marked with an asterisk were especially prominent. If the above positions are plotted, and special emphasis is placed on those groups marked with an asterisk, it will be noticed that they tend to cluster between longitudes 160° and 210°. If the meridians of 85° and 265° are taken, it will be seen that all these groups, with the exception of three, are confined at the most to one hemisphere. In Fig. 1 the serial numbers of the groups are plotted in the positions of these groups and blocks marked for the numbers which are marked with an asterisk in the table.

The method may be objectionable in so far as it is biased in considering only large groups or centres of sunspot activity. To overcome this to some extent, the number of groups in each 40° of longitude were counted for each solar rotation with the following results:

Rotation No.	Solar Longitudes.								
	360° 320	320° 280	280° 240	240° 200	200° 160	160° 120	120° 80	80° 40	40° 0
1115	3	2	1	5	6	5	0	3	3
1116	1	2	3	9	5	2	1	4	4
1117	–	–	–	–	–	–	–	–	–
1118	1	–	–	4	5	1	2	1	3
1119	1	0	3	0	5	2	3	2	0
1120	1	3	2	1	6	2	3	1	3
1121	1	5	1	4	–	1	3	5	2
1122	1	4	4	0	3	4	1	0	4
1123	3	–	0	2	2	4	1	0	5
1124	3	2	4	1	3	1	4	2	3
1125	2	2	1	3	5	3	1	1	4
1126	3	3	3	4	4	2	2	4	1
1127	3	3	1	1	2	3	3	1	2
TOTALS	23	26	23	34	46	30	24	24	34

As insufficient observations were made during rotation No. 1117 no figures are given for that rotation. It will be seen that during the year more groups have appeared in the region 160° to 200°

than in corresponding regions. This region shows up slightly in the figures for each rotation.

If there was a zone of such activity on the sun, then we should expect it to be apparent when considering the numbers of sunspots seen each day. It is practically impossible to attain to the regular observation of the sun that one would like, but by plotting the daily numbers as observed, several instructive results are obtained.

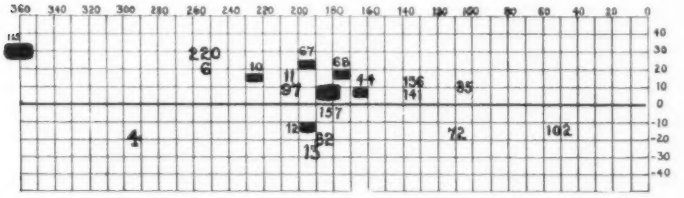

Fig. 1. The positions of the largest and most active groups, plotted by serial number. The numbers marked with an asterisk in the table are blocked in on the figure, but the size does not indicate actual area.

It would be expected that such a graph would consist of continual oscillations in the ordinates (number of sunspots) and it might be thought, therefore, that the occurrence of any maxima are somewhat accidental. It is soon apparent, however, that there is a real rise and fall as shown by daily sunspot numbers. From the Wellington observations the following maxima were obtained, and the corresponding longitudes were tabulated.

Date of Maximum			Longitude
1937	February	1	184°
	February	28	188
	April	25	170
	May	20	199
	June	17	189
	July	31	326
	September	13	105
	October	1	227
	October	18	3
	October	31	192
	November	19	301
	December	14	332
	December	29	134

In the first half of the year the agreement is very close, and this agrees with the general appearance of the sun. An apparent return to the state of affairs existing at the beginning of 1937 is shown in the 1938 January records by the appearance of a large spot near the suspected zone. Again if the above table is considered from the point of view of the hemisphere between 85° and 265° it will be seen that only four maxima occur outside of the hemisphere.

The last trial to see if such a zone existed was to note the positions of groups which returned.

Serial No. of Group	Longitude	Latitude	Rotations when Visible
12	202°	−11°	1115, 1116, 1117, 1118
23	70	+17	1115, 1116
27	28	− 6	1115, 1116
63	38	+18	1117, 1118
67	193	+22	1118, 1119, 1120
68	174	+17	1118, 1119, 1120
72	110	−19	1118, 1119, 1120
82	191	−16	1119, 1120, 1121
83	165	−17	1119, 1120
84	142	+ 9	1119, 1120
85	106	+10	1119, 1120
88	115	+13	1119, 1120
90	350	+11	1120, 1121
94	298	+10	1120, 1121
102	63	−15	1120, 1121
104	305	−19	1121, 1122
106	283	+12	1121, 1122
115	358	+28	1121, 1122
129	104	+11	1122, 1123
136	150	+11	1123, 1124, 1125
158	193	−10	1124, 1125
175	245	+10	1125, 1126
180	204	+ 8	1125, 1126
192	322	+ 6	1126, 1127

At first sight these groups are rather disappointing, but if they are plotted on a projection of the sun, it will be seen that they appear to cluster between longitudes 105° and 205°. Moreover it will be noticed that no group outside these limits returned more than once. A maximum appears somewhere near the 180th

meridian. We might again divide the sun into zones of 40° in longitude and it will be seen that a maximum near 180° is much more evident.

Zone.	No. of Recurring Groups.
0° – 40°	2
40 – 80	2
80 –120	4
120 –160	2
160 –200	5
200 –240	2
240 –280	1
280 –320	1
320 –360	3

The above results have been obtained from observations made with the 5-inch refractor of the Wellington Philosophical Society by the writer, and by Mr. R. C. Hayes when the writer was absent from Wellington. It is hoped that other workers with more complete data will investigate the suggestion made in this note.

Dominion Observatory,
Wellington, New Zealand.

MOLECULES*

By N. V. Sidgwick

IT is commonly assumed that chemistry, like physics, can prevail everywhere, but on inquiry it can be readily seen that this is by no means so; it is only under rather exceptional conditions that chemical processes can occur. This is a matter which concerns every one, and not chemists alone, because it is only where chemistry is possible that life is possible. Indeed, that is one reason why the limitations of chemistry have not always been recognized, because we are enclosed within the same limits ourselves.

Chemistry is commonly called molecular physics: it is the investigation of the structure and behaviour of those little groups of atoms which we call molecules, whose almost infinite repetition constitutes the chemical substances of our ordinary experience. The first point therefore is to know what molecules are, and in general terms why they are formed.

The matter of the universe consists of atoms, of some 90 to 95 different elements. Each atom is made up of a small positively charged nucleus, surrounded by a number of electrons equal to the number of units of positive charge on the nucleus. Now the electrons surrounding a nucleus can arrange themselves in groups of greater or less stability, and it often happens that two or more atoms can make a more stable arrangement of their electrons by pooling them or by transferring some of them from one atom to the other. If the extra stability so gained is great enough, the atoms will remain attached to one another, and a molecule will have been formed. It is only a few of the outermost electrons of any atom which take part in these rearrangements—the greater number are already sorted out into groups—and in consequence the number of atoms which forms a molecule is never large, often only two or three, and rarely more than a hundred.

It is the business of chemists to examine the behaviour, both physical and chemical, of molecules, to determine with the help of

*Portions of the Maiben Lecture before the American Association for the Advancement of Science, Denver, June 23, 1937. The lecturer is from Lincoln College, University of Oxford. Printed in full in *Science*, October 15, 1937.

the physicists their structures, and to find the relations between the structures and the properties.

If this is so, the first thing that is obvious is that chemistry can only occur where there are molecules, and that chemical processes can only occur where these molecules react with one another. This imposes definite limits on the sphere of chemistry, limits which in a sense are surprisingly narrow. We can arrive at an idea of these limits in two ways, either by direct observation or by deduction from the general principles of physics; as I hope to be able to show, the results of these two methods agree. For the observational method we have to rely on astronomy, except so far as this globe is concerned. The progress of that science during the last hundred years has shown that the composition of the matter in all parts of the universe is much the same, that the stars are made up of the elements which we know on earth, and that the same laws of nature hold elsewhere as we find here. Thus we can apply our knowledge of the behaviour of matter on the earth to other parts of the universe with a fair prospect of success.

The most obvious characteristic in which different stars differ is their temperature. The heat of a body is due to the agitation of its molecules, and the energy of this agitation is proportional to the temperature. Throughout the universe the temperature varies widely, from a very few—say two or three—degrees above the absolute zero in empty space, or in very old or very small bodies such as the moon, up to several millions (even hundreds of millions according to some physicists) of degrees in the centre of large stars like the sun.

Our knowledge of the composition of the stars (and much of our knowledge of their temperature, too) is derived from the study of their spectra; every element or compound has a characteristic spectrum, and from either the light emitted by a star or that absorbed when light from another source passes through its atmosphere, we can discover the nature of the substances composing that atmosphere. The story of the way in which these problems have been solved is a most fascinating one, but it would take too long to discuss it here; on the molecular side the fundamental work is largely due to Rupert Wildt in Germany, but much of the conclusions have been worked out by Professor H. N. Russell, of

Princeton, who has described them in his Halley Lecture (Oxford, 1933) and more especially in the address which he gave at Pittsburgh as the retiring president of this Association.*

From these investigations it appears that in the sun's atmosphere with a temperature in the parts we can see of about 6,000° Abs., there are practically no molecules at all; even those which are most stable at high temperatures, such as the cyanogen radical CN, can scarcely be detected. We may therefore take this temperature of 6,000° Abs. as being the highest temperature at which chemistry can exist. This is nearly twice the temperature of the electric arc, which is the highest temperature that we can produce artificially in any considerable space. At any temperature lower than this we shall find molecules existing wherever there is matter.

But at very low temperatures, say at the boiling point of liquid air—180°C. or 100° Abs.—though there must be plenty of molecules, there will be very little chemistry. Chemistry implies not only the existence but also the reactions and interconversions of molecules, and we can show that at such low temperatures the great majority of molecules do not react.

It is therefore evident from our observation of the behaviour of matter that the scope of chemistry in the universe is strictly limited; it can exist only where it is neither too hot nor too cold. Moreover, these limits are fairly narrow. The temperature of different parts of the world varies, as we have seen, from about 2° Abs. in interstellar space to at least 40 million and perhaps as much as 1,000 million in the centres of some stars, that is, in the ratio of 20 millions, or perhaps 500 millions, to one, or, in the terminology of the musical scale, over 24 octaves on the lower estimate and 30 octaves on the higher. The range over which we may consider chemical reaction to be possible to any considerable extent is from 100° Abs., the boiling point of liquid air, to 6,000°, the temperature of the outer layers of the sun's atmosphere, and this is a ratio of 60:1, or less than 6 octaves—say from a quarter to a fifth of the whole scale.

It is thus clear that the phenomena of chemistry are not universally diffused; they are confined to particular parts of the world where it is neither too hot for molecules to exist nor too cold for them to react. If these considerations merely defined the

*Printed in *Nature*, vol. 135, p. 219, 1935; and in *Science*, vol. 81, p. 1, 1935.

province of the chemist, we might say that they were of small interest to any but chemists; but they go much further than this. It is quite clear that without chemistry there can be no life. Even the simplest of living organisms are made up of molecules of great complexity, and their life depends on the occurrence of chemical changes among these molecules. Living organisms can endure very diverse conditions, but the limits between which molecules can exist and react are final. It is only within them that life can be carried on.

. . . . . .

To sum up, it would seem that life will be mainly confined to the surface of the planet on which it occurs, owing to the necessity of its receiving radiant energy. This planet must not be too small or the atmosphere will be lost, as has happened on the moon. On the other hand, it must not be too large: if its atmosphere is too dense, the radiation from which the life derives its energy will be cut off by the upper layers, and not enough will reach the surface, where practically all the living organisms must be. The prevalent temperature must be on the average between the boiling and the freezing point of water, though a slight excess or defect beyond these limits is possible. This is of course the most serious limitation of all. The freezing point of water is 273° Abs.; the boiling point depends on the atmospheric pressure, but as we must not have too dense an atmosphere we shall be safe if we say that the boiling point will not lie above 500° Abs. (227° C.), which is its value under 27 atmospheres pressure. This gives us a temperature range of only 500-300 or less than one octave out of the 24 or 30 octaves that occur in nature.

The application of these conclusions to the universe is a matter for the astronomers. The conclusions are not of course confined to the solar system, though there is a difficulty in applying them anywhere else, since all the stars that we can see are too hot, and life could only occur on their planets, which are too small to be visible. As far as the familiar planets of our own system are concerned, they only confirm the views that have long been held. The moon is much too small for life to be possible; Mercury is probably too small and too hot; Jupiter and the outer planets are too cold. The only places in the solar system where life is possible seem to be the earth and our two neighbours, Mars and Venus.

GEORGE ELLERY HALE
1868-1938

By A. Van Maanen

ALTHOUGH the end had been expected for some time, the death of George Ellery Hale on February 21, 1938, came as a severe shock to the astronomical world and to his many friends here and abroad. In Hale astronomy loses one of its foremost pioneers.

In the short space available it will not be possible to enumerate all he has accomplished, but I hope to touch on some of the highlights of his career.

In pure research work Hale concentrated especially on the sun, and his discovery of magnetic fields in sunspots in 1908 and of the general magnetic field of the sun in 1912 are two accomplishments which alone would make him an outstanding figure in astrophysics. But Hale was not only a man of research; he was also keenly interested in the devising of new instruments, and was responsible for the invention of the spectroheliograph, the tower telescopes, and the spectrohelioscope. His scientific publications are to be found mostly in the *Publications of the Yerkes Observatory* and the *Contributions of the Mount Wilson Observatory*. At the same time he was an extremely good writer of more popular books; his "Study of Stellar Evolution", "Ten Years of a Mountain Observatory", and his articles in *Scribners'*, which later appeared in book form, are all pleasant and interesting reading for the layman, as well as for the astronomer.

But most of all he stands out as the great organizer. In 1890, when 22 years of age, Hale built the Kenwood Observatory; in 1895 he was responsible for the building of the Yerkes Observatory, of which he was director from 1895 until 1904; he then started the Mount Wilson Observatory of the Carnegie Institution of Washington, and, after his retirement as director of the Mount Wilson Observatory in 1923, his private observatory for solar research in Pasadena.

Hale was also largely responsible for the building of the 200-inch telescope; while it is to be regretted that he did not survive until the completion of this instrument, its progress was far enough advanced

PLATE IV

GEORGE ELLERY HALE

for him to realize that the instrument would be in active use within a few years.

His organizatory talents were also responsible for the birth of several scientific journals; from 1892 to 1895 he was editor of *Astronomy and Astrophysics,* which was later transformed into the *Astrophysical Journal.* The rejuvenation of the National Academy of Sciences in Washington and the foundation of its *Proceedings* were also due to Hale.

Hale also established the International Union for Co-operation in Solar Research in 1904; when this organization was broken up during the world war, he used his efforts, during and after the war, to start the National and later the International Research Council, of which the several international Unions are the result.

While most of these activities had a national or international scope, there is one city which owes to Hale practically its whole cultural existence. In looking backward to the small town that Pasadena was when Hale started the Mount Wilson Observatory, one is interested to see the change. Outside the Observatory Hale gave a great deal of his time and energy to the whole cultural life of his city. It was he who was mainly responsible for the present state of the California Institute of Technology, as well as for the retention in Pasadena of the Huntington Library and Art Galleries and for its development as a research organization—two institutions which have now reached a standing of international renown.

When one tries to analyse how one man could be responsible for so many important things, all those who have known Hale will realize that such was possible only on account of his unbounded enthusiasm. This he would instil into his fellow-workers; with this he could make many people give their energy as well as their money to attain a worthy end. And they all loved to co-operate with him. He was most generous in giving full credit to everyone and always preferred to stay in the background when any publicity was concerned. His modesty in this respect may not have given his works the public appreciation they deserve; but it made him, on the other hand, most beloved by all who knew his activities. How much he was loved by the scientific men abroad is evidenced by the fact that when one

arrived there practically the first question they would ask was, "And how is Hale?"

It was due to Hale that so many scientific men were willing to come to Pasadena either to stay or for longer or shorter visits. His point always was to get not only the best equipment possible, but also to get men who could use that equipment to its full capacity.

On account of ill health Hale felt obliged to resign in 1923 as director of the Mount Wilson Observatory; although he was appointed honorary director, he seldom came back to the Observatory; but his spirit remained, even when it became necessary to have less and less contact with his former staff in order to save his strength for other purposes; and there is no doubt that his spirit will still survive for long to come.

Carnegie Institution of Washington,
Mount Wilson Observatory,
March 9, 1938.

METEOR NEWS

Observations relating to meteors and meteorites are cordially invited.

A List of the Meteorites of the Soviet Union

By I. S. Astapowitsch

The following list contains, as far as possible, all authentic Soviet Union meteorites recognized up to Jan. 1, 1938.

No.	Meteorite	Type	Fell	Found	Museum	Nininger No.
1	Abakan	O	.....	1891	A.S.	
2	Augustinowka	O	.....	1890	"	R 2
3	Alexandrowskij Chutor	C	1900 July 7	....	L.U.	R 1
4	Andrjuschki	C	.....	1898	A.S.	
5	Bachmut	C	1814 Feb. 15, 12*h*	....	"	R 3
6	Belaja Zerkow	C	1796 Jan. 15	....	"	R 10
7	Belokrinitschje	C	1887 Jan. 1	....	"	R 9
8	Berdjansk	P	.....	1878	L.U.	R 4
9	Bisch-Tübe	O	.....	1888	A.S.	S 3
10	Birüssa	O	.....	after 1900	"	
11	Boguslawka	H	1916 Oct. 18, 11*h* 47*m*	....	"	S 5
12	Bodajbo	O	.....	1909	"	S 4
13	Boriskino	C	1930 Apr. 20, 13*h* 30*m*	....	"	
14	Borowaja	O	.....	1885	"	
15	Borodino	C	1812 Sep. 5, 1*h*	....	L.U.	R 5
16	Botschetschki	C	1823 (End of year)	....	A.S.	R 6
17	Bragin	P	.....	1810	"	R 7
18	Brient	C	1933 Apr. 19	....	"	
19	Chmelewka	C	1929 Mar. 1, 5*h* 24*m*	....	"	
20	Demina	C	1911 Sep. 6, 15*h* 30*m*	....	"	S 6
21	Doroninsk	C	1805 Apr. 6, 17*h*	....	"	S 8
22	Dorofeewka	H	.....	1910	"	S 7
23	Erofeewka	C	1925 Feb. 8-9	....	"	
24	Grosnaja	C	1861 June 28, 19*h*	....	"	R 12
25	Grossliebental	C	1881 Nov. 19, 6*h* 30*m*	....	O.U.	R 13
26	Indarch	C	1891 Apr. 7, 20*h* 10*m*	....	A.S.	R 14
27	Itschkala	C	1936 May 29, 19*h* 34*m*	....	"	
28	Kawkas	C	.....	after 1900	"	
29	Kagarlyk	C	1908 June 30(?)	....	"	R 16
30	Kainsas	C	1937 Sep. 14	....	"	
31	Kaptal Aryk	C	1937 May 12	....	"	
32	Karagaj	C	.....	after 1900	"	
33	Karakol	C	1840 May 9, 12*h*	....	"	S 9
34	Kaschin	C	1918 Feb. 27, 12*h* 45*m*	....	"	R 11
35	Kikino	C	1809	....	Budapest	R 18
36	Krasnyj Ugol	C	1829 Sept. ?	....	A.S.	R 20
37	Kuleschewka	C	1811 Mar. 12, 11*h*	....	"	R 21
38	Kusnezowo	C	1932 May 26, 17*h* 30*m*	....	"	PA 17
39	Kulp	C	1906 Mar. 29	....	"	R 22
40	Lebedinnyj	O?	.....	1925	?	
41	Leonowka	C	1900 Aug. 23, 21*h*	....	A.S.	R 24
42	Lipowskij Chutor	C	.....	1904	Ch.U.	R 25
43	Lubimowka	C	1936 Apr. 2	....	A.S.	
44	Malyj Altaj	P	.....	after 1900	"	
45	Mamra	C	1927 May 15	....	"	S 20
46	Medwedewa	P	.....	1749	"	S 10
47	Migei	C	1889 June 18, 8*h* 30*m*	....	O.U.	R 27
48	Muroznaja	O	.....	1885	A.S.	
49	Netschajewo	C	.....	1846	"	R 30
50	Nikolajewka	C	1935 Aug. 4, 16*h*	....	"	

No.	Meteorite	Type	Fell	Found	Museum	Nininger No.
51	Niro (Werchne-Udinsk)	O	.....	1854	"	S 18
52	Novyj Urej	C	1886 Sep. 4	....	L.U.	R 31
53	Norin-Schibir	O	.....	after 1900	A.S.	
54	Nochtujsk	O	.....	1876	London	S 11
55	Orlovka	C	.....	1928	A.S.	
56	Ochansk	C	1887 Aug. 30, 13*h*	....	"	R 34
57	Otscheretnaja	C	.....	1871	London	R 35
58	Pawlowka	Go	1882 Aug. 2, 17*h*	....	Budapest	R 38
59	Pawlograd	C	1826 May 19	....	Tartu	R 37
60	Perwomajskij	C	1933 Dec. 26, 18*h*	....	A.S.	PA 30
61	Petropawlowka	Ac	.....	1916	"	
62	Petropawlowsk	O	.....	1841	L.U.	S 13
63	Rakowka	C	1878 Nov. 20, 15*h*	....	M.U.	R 40
64	Repeew Chutor	O	1933 Aug. 8, 20*h*	....	A.S.	PA 28
65	Retschki	C	1914 Apr. 9, 13*h* 30*m*	....	"	R 41
66	Sawtschenskoje	C	1894 July 27	....	O.U.	R 44
67	Saratow	C	1918 Sep. 6, 15*h*	....	A.S.	R 42
68	Sarepta	O	.....	1854	"	R 43
69	Sewrükowo	C	1874 May 11, 23*h* 45*m*	....	"	R 45
70	Slobodka	C	1818 Aug. 10	....	"	R 48
71	Stawropol	C	1857 Mar. 24, 17*h*	....	"	R 49
72	Staroje Pesjanoje	C?	1933 Oct. 2, 6*h*	....	"	PA 29
73	Sungatsch	C	1935 Apr. 10	....	"	
74	Ssyromolotowo	O	.....	1873	"	S 14
75	Tarbagataj	C	.....	after 1900	"	
76	Teleutskoje Osero	Ac	1904 May 20	....	"	S 1, S 19?
77	Timochina	C	1807 Mar. 25, 15*h*	....	"	R 51
78	Tomakowka	C	1905 Jan. 17, 21*h* 30*m*	....	"	R 52
79	Tschinge	At	.....	1913	"	
80	Tschuwaschskije Kissy	C	.....	1899	K.U.	R?19
81	Tubil	O	.....	1891	A.S.	S 15
82	Tunka	C	1824 Mar. 1, 7*h*	....	Wien	S 16
83	Uderej	O	.....	1885	A.S.	S 2
84	Wawilowka	Ac	1876 June 19, 14*h*	....	O.U.	R 53
85	Werchne-Tschirskaja	C	1843 Nov. 12, 12*h*	....	A.S.	R 55
86	Yamyschewa	P	.....	1885	"	S 12?
87	Zaborica (Saboriza)	C	1818 Apr. 11	....	"	R 56
88	Zigajlowka	C	1787 Oct. 12, 15*h*	....	"	R 17
89	Zmeni	Go	1858 Aug.	....	Wien	R 58
90	Laurentjevka	C	1938 Jan. 11, 14*h* 30*m*	....	A.S.	

Supplementary List of Meteorites from Territory Formerly Russian

Bragin-Kuzowka	P	.....	1810	A.S.	
Bragin-Kruki	P	.....	1810	"	
Pultusk	C	1868 Jan. 30	....	"	CE 34
Dolgaja Wolja	C	1864 June 26	....	"	CE 7
Belostok	Ac	1897 Oct. 5	....	"	CE 2

Abbreviations

A.S.— Lomonossov's Institute of the Academy of Sciences, Moscow.
Ch.U.— Charkov University.
O.U.— Odessa University.
L.U.— Leningrad University.
M.U.— Moscow University.
K.U.— Kazan University.
C— Chondrite.
R— List of Russian meteorites, Our Stone-Pelted Planet, p.202, 1933.
S— List of Siberian meteorites, Our Stone-Pelted Planet, p.206, 1933.
PA— List in Popular Astronomy, v.45, p.451, 1937.
CE— List of Central European meteorites, Our Stone-Pelted Planet, p.193, 1933.
Ac— Achondrite.
O— Octahedrite.
H— Hexahedrite.
P— Pallasite.
Go— Gowardite.
At— Ataxite.

Moscow University,
Moscow, U.S.S.R.

Recent Lists of Meteorites

Meteorites are the only samples of material from the universe outside the earth which we can study at close quarters and since each meteorite has its own individuality it is extremely important that the list of all the authentic meteorites of the world be made as complete as possible. Dr. H. H. Nininger, President of the Society for Research on Meteorites, has rendered a great service to science by following up and locating many recent American falls and generally arousing the public interest in the study of meteorites. Nininger also published in 1933, as an appendix to his book "Our Stone-Pelted Planet," a list of the meteorites of the world, which was made as complete as possible. This was followed by a supplementary list of 100 meteorites by A. D. Nininger in *Popular Astronomy*, vol. 45, p. 449, 1937, giving all additional meteorites reported to the Society for Research on Meteorites up to June 1937. These two lists contain in all 1127 falls and finds. The records from some countries, especially for falls and finds of recent years, were admittedly incomplete.

The writer has received for publication a complete list of the meteorites of the U.S.S.R., prepared by Dr. I. S. Astapowitsch of the Moscow Astronomical Institute. This contains 24 finds and falls which are not listed by Nininger and the complete list received will be found on pp. 195-6.* Dr. Astapowitsch mentions that in some cases the English spelling of the Russian names is provisional. For ease in cross reference I have taken the liberty of adding the number in the Nininger lists in the last column of the table. It will be noted that 7 cases included by Nininger have been omitted as being apparently of doubtful authenticity. Among these is the great Tunguska fall of 1908 which is quite properly left out of a list of meteorites since no meteorite has yet been recovered from the location of this fall.

The writer has prepared two maps to accompany the above-mentioned list. These should be regarded as of a preliminary nature and may contain some errors as in many cases the district of the

*As this was going to press a communication from Astapowitsch was received describing a new fall on Jan. 11, 1938, and this has been added as No. 90 in the table.

Fig. 1. Preliminary map showing location of the meteorites of the U.S.S.R. in Europe.

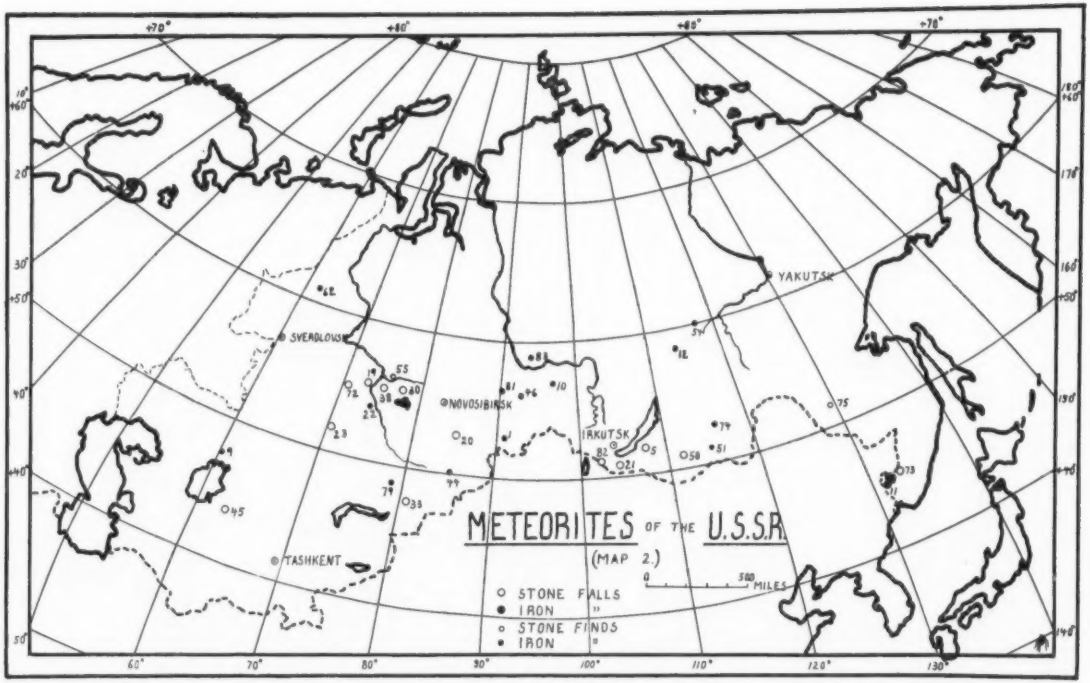

Fig. 2. Preliminary map showing location of the meteorites of the U.S.S.R. in Asia.

U.S.S.R. was not given. With the maps available in Toronto it was found difficult to determine the exact location of some of the meteorites and for a few the points had to be omitted. The maps will probably prove to be of interest, however, even in their incomplete state.

A preliminary list of Japanese meteorites was published a few years ago by Prof. I. Yamamoto in Kwasan Observatory Bulletin, No. 306, 1935. This publication seems to have been generally overlooked by students of meteorites. It lists 39 or 40 Japanese falls and finds, of which Nininger mentions only 15. This may possibly be due to a limited circulation of the Kwasan Bulletin outside of Japan. In the interests of completing the meteorite records it seems worth while to reproduce Yamamoto's list in a somewhat condensed form, especially since some parts of the table are not given in English. It will be found in Table I. Some small liberties have been taken in slightly rearranging the table. Each fall or find is listed only once instead of making a separate entry for each fragment as in the original. The English spellings of Japanese place names have been changed in some cases to conform to a generally accepted convention. One fall, where the meteorite was apparently never found, has been omitted, and three other somewhat uncertain cases have been moved to the end of the table. The Nininger number for those previously listed is inserted in the last column. The time of day given in the accompanying lists is is presumably the local standard time.

Because most of the Japanese names represent very small places, not found on ordinary maps, I have prepared a map to indicate the general distribution of these meteorites. While there may be a slight inaccuracy in the plotted positions in a few cases they are believed to be essentially correct as far as general location in concerned.

Yamamoto's table has a feature which appeals to the writer very much. The finds and falls are listed chronologically which seems to be a much more logical scientific method than a listing according to the Arabic spelling of the name. The latter method, though generally adopted, is far from international in import and runs into the difficulty of alternative English spellings of foreign

names as well as alternative names for the same meteorite.* A better method would seem to be to separate the falls from the finds, which statistically should never be treated together in any case, and to list each chronologically. In the case of the falls the order of listing would then have a true scientific meaning and while listing the finds in order of discovery or recognition is not particularly significant, it is at least as good on that count as an alphabetical listing, with the added advantage of being equally intelligible in any language.

Another bibliography of meteorites has appeared recently, F. Heide, *Fortschritte der Mineralogie, etc.*, vol. 21, p. 225, 1937, and this includes 37 meteorites not mentioned by Nininger. For the convenience of those to whom the German publication is not available these additional meteorites are listed in Table II. In one or two cases they may possibly occur in Nininger's lists (e.g. No. 29) but the description of the objects did not tally so they were included here also.

With no pretense at completeness a few additional meteorites recently mentioned in the scientific literature are given below:

Baxter, Stone Co., Mo., U.S.A., stone, fell 1916, Science v. 87, p. 234, 1938.

Phulmari, Hyderabad, India, stone, fell few years before 1936, P.A. v. 44, p. 563, 1936.

New Caledonia, stone, fell July 16, 1936, C.R. 204, Mar. 1, 1937.

Tanezrouft, W. Sahara, stone, found 1936, C.R. 203, Nov. 9, 1936.

Komarinsk District, White Russia, iron, found 1937, Science, Oct. 15, 1937, supplement p. 14.

Meteorite Statistics

The Nininger lists, together with those accompanying this note, contain just over 1,200 different meteorite falls and finds. The approximate distribution of these, both over the surface of the earth and in regard to time is indicated in Table III. As is natural,

*A noted example of this is the Homestead fall which should more properly be called Amana.

TABLE I.—A List of the Meteorites of the Japanese Empire

(Condensed from a list by Issei Yamomoto in Kwasan Observatory Bulletin, 306, 1935)

No.	Meteorite	Type	Fell	Found	Prefecture "Ken"	District "Gun"	Nininger No.
1	Suwa	I		?	Nagano	Suwa	
2	Ogasawara	I		?	Tokyo Fu		
3	Ogi	C	1741 Aug. 8, 11*h*	....	Saga	Ogi	J 8
4	Hachi-oji		1817 Dec. 29	....	Tokyo Fu		
5	Yonoozu	C	1837 July 14, 16*h*	....	Niigata	Nishi Kambara	J 15
6	Fukue	O		1842	Nagasaki	Goto Jima	
7	Kesen	C	1850, June 12, 5*h*	....	Iwate	Kesen	J 5
8	Sone	C	1866 May 14, 12*h*	....	Kyoto Fu	Funai	J 12
9	Otomi	S	1867 May 24	....	Yamagata	Kita Murayama	J 10
10	Nagareyama			1872	Chiba		
11	Takenouchi	C	1880 Feb. 18, 5*h* 30*m*	....	Hyogo	Yabu	J 13
12	Fukutomi	C	1882 Mar. 19, 13*h*	....	Saga	Kinoshima	J 1
13	Tanakami	O		1885	Shiga	Kurimoto	J 14
14	Oshima	C	1886 Oct. 26, 15*h*	....	Kagoshima	Isa	J 6
15	Kanzaki	C		?	Saga	Kanzaki	J 4
16	Shirohagi	I		1890	Toyama	Niikawa	J 11
17	Saotomi	(S?)		1890	Toyama		
18	Nio	C	1897 Aug. 8, 22*h* 30*m*	....	Yamaguchi	Yoshiki	J 7
19	Hakata	C	1897 Aug. 11	....	Fukuoka		J 3
20	Okano	H	1904 Apr. 7, 6*h* 35*m*	....	Hyogo	Taki	J 9
21	Kijima	C	1906 June 15	....	Nagano	Shimo Takai	
22	Gifu	C	1909 July 24, 5*h* 44*m*	....	Gifu	Mugi; Yamagata	J 2
23	Sakouchi	O	1913 Apr. 13	....	Gifu	Ibi	
24	Tomita	C	1916 Apr. 13	....	Okayama	Asakuchi	
25	Tane	C	1918 Jan. 25	....	Shiga	Higashi Asai	
26	Nanseiseki	SI	1920 Aug. 13	....	Shantung China	Chodenyaku	
27	Hataya	C		1920	Akita	Semboku	
28	Kusiike	C	1920 Sept. 16	....	Niigata	Naka Kubiki	
29	Unkoku	C	1924 Sept. 7	....	Zenranando Korea	Shura	
30	Numakai	C	1925 Sept. 6	....	Hokkaido	Ishikari	
31	Urasaki	S	1926 Apr. 16	....	Hiroshima	Numakuma	
32	Aba	S	1927 Apr. 28	....	Ibaraki	Inashiki	
33	Yoshiki	S	1928 June 25	....	Yamaguchi	Yoshiki	
34	Zindoo	C	1930 Mar. 17	....	Keishohokudo Korea		
35	Kurumi	C	1930 May 27, 12*h*	....	Hyogo	Mino	
36	Sakurayama	I	1935 July 7	....	Nagoya Shigai		
	Uncertain Cases						
37	Shiriya	S?	1883 Oct. 24	....	Aomori		
38	Ida		1929 Oct. 10	....			
39	Sano			1925	Totigi		

Abbreviations

C Chondrite — O Octahedrite
S Stone — H Hexahedrite
SI Stony-iron — I Iron

J—List of Japanese meteorites, Our Stone-Pelted Planet, p.218, 1933.

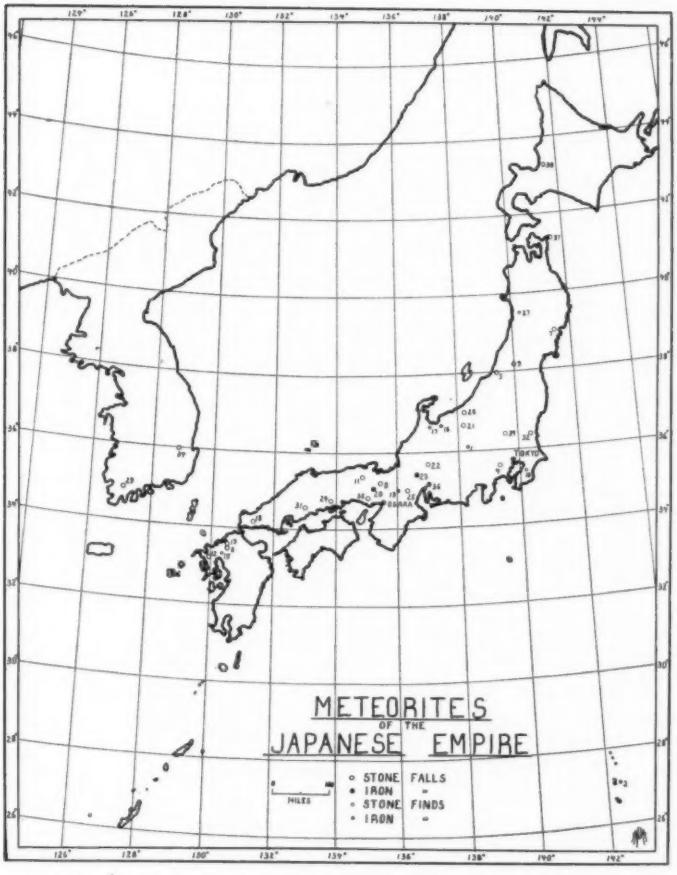

Fig. 3. The geographical distribution of Japanese meteorites.

[Addendum:—No. 14, lat. 31.°7 N, long. 130.°5 E
No. 33, lat. 34.2 N, long. 131.4 E]

TABLE II.—Meteorites in Heide's List not Included by Nininger
(Heide, F. der Mineralogie, etc., vol. 21, p. 225, 1937)

Meteorite	Location		Type	Fell	Found
Europe					
1. Bettrechies	50°.3 N, 3°. 7 E	France	S	Nov. 26, 1934	
2. Chaves	Troz-os-Montes	Portugal	S	May 3, 1925	
3. Drevdalen	Trysil	Norway	S	June 21, 1927	
4. Oteroy	Kragerö	Norway	S	Oct. 15, 1928	
5. Padvarninkai	55°.7 N, 28°.4 E	Lithuania	S	Feb. 9, 1929	
6. Pontlyfni	53°.0 N, 4°.3 W	England	S	Apr. 14, 1931	
7. Prambach-kirchen	48°.3 N, 14°.0 E	Austria	S	Nov. 5, 1932	
8. Sazovice	49°.2 N, 17°.6 E	Czechoslovakia	S	June 28, 1934	
9. Sopot	Dolj	Rumania	S	Apr. 27, 1927	
10. Zemaitkiemis	55°.3 N, 25° E	Lithuania	S	Feb. 2, 1933	
Asia (except India)					
11. Beyrouth		Syria	S	Dec. 31, 1931	
12. Buwah	20°.1 N, 51°.4 E	S. Arabia	S		1931
13. Dyarrl Isl.		New Guinea	SI	Jan. 31, 1933	
14. Liweipantsün	Kiangsi	China	S	Aug. 27, 1931	
15. Phum Sambo	Kompong Cham	Cambodia	S	Jan. 9, 1933	
16. Wabar	21°.5 N, 50°.7 E	S. Arabia	I		1932
India					
17. Khanpur	25°.6 N, 83°.1 E	India	S	July 8, 1932	
Africa					
18. Air	19°.1 N, 8°.4 E	Niger Col.	S	about 1925	
19. Amun	Thebes	Egypt	I		
20. Birni N'Konni	13°.8 N, 5°.3 E	Niger Col.	S	Apr.-May 1923	
21. Bowden	Cape Province	Un. S. Africa	S		1907
22. Douar Mghila	32°.3 N, 6°.3 W	Morocco	S	Aug. 20, 1932	
23. Tataouine	Gabès	S. Tunis	S	June 27, 1931	
Australia—New Zealand					
24. Bencubbin	30°.8 S, 117°.8 E	W. Australia	SI		1930
25. Morven	44°.8 S, 171°.1 E	New Zealand	S		1925
North America					
26. Grant	Valencia Co.	New Mexico	I		1929
27. Lafayette		Indiana	S		1931
28. Lanton	Howell Co.	Missouri	I		1932
29. Santa Fé		New Mexico	I		1930
30. WashingtonCo.		Colorado	I	about 1916	
South America					
31. Barbacena	Minas Geraes	Brazil	I		1918
32. Cerros del Buei Muerto	22°.5 S, 69°.9 W	Chile	I		1927
33. Hinojo	Buenos Aires	Argentine	S		
34. Isthilart	Concordia	Argentine	S	Nov. 12, 1928	
35. Piedade do Bagre	18°.9 S, 45°.0 W	Brazil	I		1922
36. Renca	San Luis	Argentine	S	June 20, 1925	
37. San Martin		Chile	I		

Abbreviations

S—Stone I—iron SI—stony-iron

the greatest number of falls occur in regions which have combined dense population with general education and scientific advancement. Finds are scarce in regions that have been under cultivation for centuries but are relatively numerous in the Americas and

TABLE III.—The Distribution of 1,204 Meteorites

Region	Europe (except U.S.S.R.)	Asia (except U.S.S.R., India)	U.S.S.R.	India	Africa	Australia New Zealand	North America Central America	South America	Total Falls: Stones	Stony-irons	Irons	Totals	%
FINDS Irons	22	10	19	1	24	51	243	39				409	66
Stony-irons	4	1	5	1	0	7	21	7				46	7½
Stones	12	7	10	2	6	24	92	12				165	26½
FALLS Irons	8	3	2	4	4	0	7	1				29	5
Stony-irons	3	2	0	2	0	0	1	0				8	1½
Stones	206	45	54	104	31	4	87	16				547	93½
Stone Falls –1800	18	1	2	2	0	0	0	0	23	0	1	24	
1800–1809	10	1	3	1	0	0	2	0	17	0	0	17	
1810–1819	13	1	5	3	0	0	0	0	22	0	0	22	
1820–1829	9	1	4	4	0	0	6	0	24	0	1	25	
1830–1839	14	1	0	4	1	0	1	1	22	0	1	23	
1840–1849	17	0	2	3	0	0	6	1	29	1	1	31	
1850–1859	19	2	2	6	1	0	5	0	35	0	0	35	
1860–1869	22	4	1	17	3	0	5	1	53	1	1	55	
1870–1879	19	2	3	10	2	0	7	4	47	1	2	50	
1880–1889	10	6	6	7	4	0	4	0	37	1	3	41	
1890–1899	16	2	2	10	2	0	13	0	45	0	2	47	
1900–1909	11	4	6	8	5	2	9	2	47	1	5	53	
1910–1919	5	6	4	16	5	0	10	1	47	0	7	54	
1920–1929	17	9	3	9	5	1	8	6	58	0	1	59	
1930–	6	5	11	4	3	1	11	0	41	3	4	48	

Australia. The percentage of irons among the finds is high, 66 per cent, while but 5 per cent of the falls are iron. This latter value probably represents an upper limit of the frequency of irons in space since they are more likely to survive the passage through the earth's atmosphere and to be recognized as meteorites after reaching the ground.

The relative numbers of falls recovered for each decade are graphically indicated in Fig. 4. It will be seen that, with the exception of two rather prolific decades between 1860 and 1880, there has been a steady and almost uniform increase in the number of falls recovered. This is undoubtedly owing to the steady spread of civilization and the awakening of popular interest in scientific matters. The smaller number recorded since 1930 is due to incom-

plete records. The average number of falls per decade since 1860 has been 51, or roughly one fall per 10,000,000 sq. mi. per year if we exclude the arctic and antarctic regions. Silberrad has shown (Min. Mag., vol. 23, p. 290, 1932) that in the United Provinces of India, where the population is dense and reporting has been at least as complete as anywhere in the world, the rate for the last

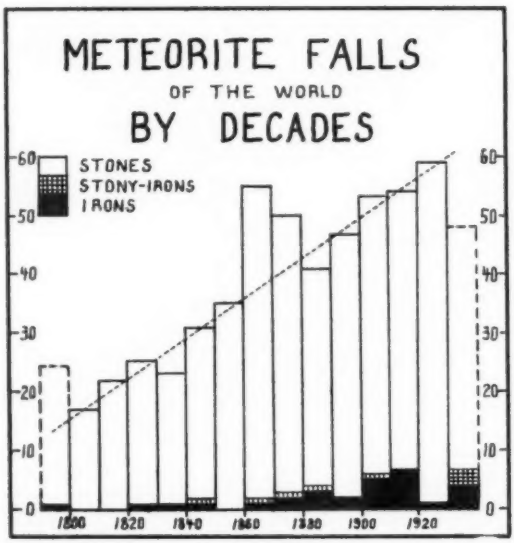

Fig. 4. The frequency of recorded meteorite falls by decades.

century has been 25 times as great or one fall per 400,000 sq. mi. per year. We may conclude that at least 25 times as many meteorites would be recorded were conditions all over the world comparable to those of the United Provinces. Canada, with an area approximately 3,500,000 sq. mi., boasts only 3 recorded falls in its whole history. Even taking Canada's small population into account, this is a low figure.

P. M. M.

NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

An Old Record of a Wonderful Fireball

The Editor has received from his friend, Dr. Jabez H. Elliott, of Toronto, the following account of the descent of a meteor into Lake Ontario as observed by the captain of a sailing vessel. It is copied from *The Volunteer Review* for November 1867. After making allowance for the tendency of the observer to estimate the place of fall of a meteoric body as much nearer than it really is and to judge the body to be much larger than it actually is, one must conclude that the fireball seen was very remarkable. Further information, perhaps from other contemporary newspapers, would be valuable.

DESCENT OF AN ENORMOUS METEOR IN LAKE ONTARIO.

A Grand and Startling Spectacle.

The Hamilton *Times* says Capt. Turner, of the schooner *Algernine*, who arrived in the city this morning, reports having witnessed at about the hour of 11 o'clock on Wednesday night, a terrific and splendid phenomenon, in the descent of an immense meteor into Lake Ontario, which struck the water not more than three hundred yards from his vessel. The Captain states that a few moments previous to the appearance he had come up from his cabin on deck, and was standing on the main hatch. The vessel was on the starboard tack, sailing along finely with a light southwest breeze for Port Dalhousie, and about twelve miles off the Niagara lighthouse, bearing S.S.W. Presently his attention was attracted by a sudden illumination from the northwest, which almost instantly increased to a dazzling brilliancy. On turning he beheld a large body of fire in the heavens, which seemed to be approaching at a descent of about 30°, and growing rapidly larger as it came nearer, the observation of time being so brief as hardly to admit of computation in seconds. The momentary impression of Captain Turner was that certain destruction awaited his vessel and all on board, as the terrific missile seemed to be directed to strike the vessel broadside. The time of reflection however was brief and the light emitted was so blinding in its effect that the man at the wheel and another of the crew on deck fell prostrate and remained for some time completely stupefied with terror. The Captain himself, as he states, remained transfixed and saw the fiery body enter the water some three hundred yards ahead of the vessel, about two points to the windward. A loud explosion attended the contact with the water, which was sharp and deafening, equal to a thunderbolt close at hand, and a large

volume of steam and spray ascended to the air, which was noticed for some moments afterwards. In the confusion of the moment, Capt. Turner was unable to comprehend what had occurred, and the crew were inclined to believe that the phenomenon was an explosion of lightning, the sky being perfectly cloudless at the time. The Captain estimates, as well as he was able to judge from the brief time for observation afforded, that the meteor was a body of about twenty feet in diameter. A long tail of flame of the most intense brilliancy was noticed as it struck the water. As Capt. Turner describes his sensation, his faculties for the moment all compressed in the sense of sight, so overwhelming was the light from the fiery object, but we believe he was sensible to a terrible whizzing, howling noise, similar to that made by the steam issuing from the escape pipe of a steamer, which attended the meteor previous to the grand explosion on striking the water. Capt. Turner arrived at Port Dalhousie on Wednesday morning. He assures us that his nervous system did not recover from the shock experienced for many hours afterwards.

Space Boat Speculations

A well-known M.D. (retired), formerly of London, Ont., prompted by the relativity limerick quoted in the February issue, writes:

I have read with avidity many "space-boat" stories, from Jules Verne to some self-written for my own amusement, but have never noted any reference to the following "possibilities"; possibilities at least, in that division of astronomy known as "speculative".

1. Admitting a space-boat capable of closely approaching the sun without damage to itself or its navigators, is it not *likely* that, besides the obvious intense heat and light, there would be also *a most intolerable noise?* Not, of course, carried by any atmosphere like ours, but by the immense belts of gas about the sun? If this be true "the silent stars" become the most frightfully noisy items of our universe—barring of course some of our actual and would-be dictators!

2. If now our space-boat navigators (moving for convenience, at the speed of light, or as much faster as celestial traffic laws may permit) should move to Jupiter or Saturn, is it not *likely* that, whatever else might be noted, the absorbing interest would be the *ghastly smells*—ammonia, methane and perhaps other products suggesting the Augean stables? May not these gases be of organic origin?

3. While much interested in the answers to the above queries in "*un*-romantic astronomy," I should be glad also to have an explanation (if one is possible, capable of assimilation by an amateur) why it is held that one "celestial traffic law" reads: "Nothing can move faster than light?" The limerick article had a reference to this question; but no answer.

I shall be grateful, Mr. Editor, if you will give me serious answers even to such apparently frivolous questions.—*H. W. Hill*, Hackensack, Minn.

Answers

1. The production of sound requires a vibrating body and its transmission demands a material medium. These seem to be present in the sun's chromosphere and hence one would expect sounds to be heard on a close approach to the sun. It should be remembered however that the radiation from the sun is not due to chemical action as in a flame and hence the vigorous motions of the gases at the surface of the sun may not give rise to sound.

2. The spectroscope reveals the presence of ammonia and methane in the atmospheres of Jupiter and Saturn and it is to be expected that, notwithstanding the low temperatures there (about $-280°$), these substances would excite the navigator's olfactory nerves as they do on the earth. The origin of these gases is beyond my conjecture.

3. I cannot assign a reason for the statement that in our universe there can be no velocity greater than that of light. Indeed this fundamental assumption in the theory of relativity seems to me arbitrary and unreal.

Can a River Run North?

We are so accustomed to the familiar phrase "down" south that some persons actually think that the southland is at a lower level than the north and therefore the rivers must run south. They are not aware that the inhabitants of Labrador continually speak of "down" north. The present writer recently heard a southern clergyman, when speaking on "Idle Tales," tell a strange story.

He said a citizen of the "Blue Grass" state paid a visit to Florida and on his return home related that there existed a river there which flowed north. His brethren refused to accept such a heretical statement and appointed a committee to investigate it. They made an excursion to the St. John river which reaches the ocean at Jacksonville at the north-east corner of the state. Now Florida is a low-lying level state and its streams are sluggish and much affected by the tides. The committee made their observations at high tide, when the water was moving in from the ocean and apparently flowing southward. They reported that the former visitor was in error and that they had seen the river flowing south.

C. A. C.

MEETINGS OF THE SOCIETY

NEW MEMBERS AT LARGE

The following members at large have been elected to the Society since November 8, 1937:

Woodall, A. M.....3321–15th Court N., Birmingham, Alabama
White, Marven.....Rosetown, Sask.
Piersol, C. W.....608 N. Pine St., Lancaster, Pa., U.S.A.
Gordon, Miss M. E.....Box 24, Whitehorse, Y.T.
McDougall, E. G.....Shalalth, B.C.
Hewitt, W. T.....1320 Terry Avenue, Seattle, Wash., U.S.A.
Davis, R. D.....1619 Boston Avenue, Muskogee, Oklahoma, U.S.A.
Gardner, R.....1441 League St., Akron, Ohio
Asquith, Eric.....Railway Hotel, Milnrow Rd., Rochdale, Lancs., England
Robinson, W. C.....Quogue, New York, U.S.A.
Douker, M.....64 Buxton St., Bloemfontein, S. Africa
Coombs, F. M.....1809 Congress St., Portland, Maine
Mowry, C. A.....142 High St., Pawtucket, R.I., U.S.A.
Atkinson, W.....2 Duke St., Penrith, Cumberland, England
McLennan, John.....1424 Oakwood Avenue, Akron, Ohio
Gordon-Hill, Mrs. R. J...Limberlost P. O., Ontario
Uhrig, Alex. B.....Oconomowoc, Wis.

AT OTTAWA

January 28, 1938.—At an open meeting of the Ottawa Centre of the Royal Astronomical Society, held at the National Museum, Mr. R. Meldrum Stewart, Dominion Astronomer, spoke about "Other Galaxies". Our own Galaxy or Milky Way, is a large cluster of stars grouped together like a watch or an enormous disc. About two-thirds the way out from the centre of this disc lies our little solar system. By accurate measurements which are made in much the same way as a surveyor measures distances on land, the distances of the sun, moon, and nearby stars have been determined. And it has been proven that the nearest star is so far from our sun that the light leaving the star travels for four and a third years before spanning the distance. This is not unusual, but rather each star, no matter how it may seem to be densely surrounded by its neighbours, is really an isolated little unit.

Beyond the range where direct triangulation methods are of use, the astronomer has been provided with another measuring rod. Certain stars vary in brightness with great regularity. And it has been noted that in the case of the Cepheid variables, the longer the period between bright peaks, the

brighter the star. Thus, knowing its period, the absolute brightness may be determined, and the apparent brightness is a measure of the distance.

Our great galaxy is really a giant mass of stars in the general form of a flat spiral. The modern telescope, equipped with the sensitive photographic plate, has revealed many hundreds of other such galaxies scattered in all directions through space. For the nearest of these, Cepheid variables which have been discovered in them have served to reveal their distances. But distances soon mount to enormous values, so that only the brightest of stars can be distinguished in the galaxies. These then are used as the measuring rod. Still further the telescopes probe, till even great galaxies of stars become as mere faint dots. Here the average brightness of the whole galaxy must be used as the measuring rod, and the story is that the light from these most distant ones has been speeding towards us for hundreds of millions of years before finally arriving here. What may have happened to that far distant object in the interval since the light which trickles through to us first started on its way, is food for speculation.

A greater puzzle confronts the astronomer. These great galaxies, which distance has reduced to small specks, appear to be racing away from us at enormous speeds of thousands of miles a second; as if our great universe were expanding in leaps and bounds. This is detected by a shift to the red end of the spectrum. Another interpretation of this shift to the red in the spectrum pictures is that the little bundles of light have suffered a loss of energy merely by reason of the distance travelled. The analogy is the loss of energy suffered by a ball due to the bombardment of millions of particles of air as the ball is thrown. Some day the puzzle may be solved, but there is still much left to tax the ingenuity of the ablest astronomer.

Mr. McLeish, director of Mines, Department of Mines and Resources, and president of the local centre, was chairman.

M. M. THOMSON, *Secretary*.

AT TORONTO

January 25, 1938.—The regular meeting of the Toronto Centre was held in the McLennan Laboratory, University of Toronto, at 8 p.m.

Vice-Chairman Mr. S. C. Brown, presided in the place of the Chairman, Mr. E. J. A. Kennedy, who was unhappily detained.

Mr. F. S. Hara, 69 Fairlawn Avenue, Toronto, was nominated for Membership in the Toronto Centre.

Mr. S. C. Brown read the list of Officers and Council resulting from the recent election of the Royal Astronomical Society of Canada.

The paper of the evening was given by Prof. E. F. Burton, Director of the McLennan Laboratory and Head of the Department of Physics in the University of Toronto, on "The Scientific Work of Lord Rutherford". Dr. Burton dealt with his subject in four divisions: Rutherford as student, as Professor

of Physics at Montreal, as Head of the Department of Physics at Manchester, and as Director of the Cavendish Laboratory at Cambridge. (It is planned to print this lecture in a forthcoming issue of the JOURNAL.) Dr. Burton, as he proceeded, illustrated his lecture with a number of experiments which the members found interesting and helpful.

Dr. Best expressed the appreciation of the members for Professor Burton's account of the work of a great scientist.

Dr. Heard resumed his lectures on the Elements of Astronomy; his subject was "Stellar Magnitudes; Distribution of Stars in Space." Beginning with an account of the manner in which the ancient arbitrary division of naked eye stars into six magnitude classes had been displaced by the modern more exact standard magnitude scales, which he explained in detail, the lecturer went on to define apparent visual magnitude, apparent photographic magnitude, colour index and absolute magnitude. Interesting reference was made to statistical surveys of the stars according to apparent magnitude, the quantitative results indicating that there is a limit to this stellar system, and that the system is a disc-shaped galaxy of some 30,000,000,000 stars closely packed towards the centre and straggling out towards the sides and edges. After Dr. Heard had answered a number of questions the meeting adjourned.

February 8, 1938.—The regular meeting of the Toronto Centre was held in the McLennan Laboratory, University of Toronto, at 8 p.m. Mr. E. J. A. Kennedy was in the chair.

Mr. F. S. Hara, 69 Fairlawn Avenue, Toronto, was elected to membership in the Society. Mr. Harold E. Mott, 101 Dufferin Avenue, Brantford, Ontario, and Mr. T. E. Cannon, 19 Marion Street, Toronto, were nominated for membership in the Society—Toronto Centre.

The Chairman then introduced Mr. D. A. MacRae, B.A., of the David Dunlap Observatory, who gave the paper of the evening on "Photography and the Astronomer." In a very interesting way Mr. MacRae described the successive steps in the making of a negative, from which with similar steps a positive can be printed and prepared, and gave much information about lenses, plates, developing solutions, fixers and washers. He then went on to give an account of the History of Astronomical Photography. The lecture was illustrated with lantern slides of early and recent photographs, showing the great progress made. There was also a carefully arranged exhibit of various materials used in photography. As the lecture proceeded a plate, exposed at the beginning, was developed, printed on a lantern slide and finally the result—a photograph of the audience—was projected on the screen.

After many questions had been answered, the Chairman conveyed the thanks of the meeting to Mr. MacRae. Dr. Heard's lecture on the Elements of Astronomy was postponed until the next meeting.

Reports of the observing sections were given by the Directors of the several sections.

February 22, 1938.—The regular meeting of the Toronto Centre was held in the McLennan Laboratory, University of Toronto, on Tuesday, February 22, 1938, at 8 P.M., with Mr. E. J. A. Kennedy in the Chair.

Mr. Harold E. Mott, 101 Dufferin Avenue, Brantford, Ontario, and Mr. T. E. Cannon, 19 Marion Street, Toronto, were elected to membership in the Society.

The paper of the evening was given by Miss R. J. Northcott, M.A., of the David Dunlap Observatory on "Percival Lowell." This interesting address began with a rapid survey of Lowell's career from his birth in Boston, Massachusetts, touching on his early interest in astronomy, his life at Harvard where he graduated in mathematics, his year of travel in Europe, his successful industrial enterprises, his subsequent travels in the Orient and writing of important books on Japan and the East. Then followed an account of Lowell's keen interest in the planets which led to the building of the Observatory at Flagstaff, Arizona, where so much important work on planetary investigation has been carried on, notably on Mars and the search for planet X now known as Pluto.

In the discussion which followed, Mr. J. R. Collins and Dr. Satterly took part. Mr. Collins recalled that Percival Lowell was a Fellow of the Royal Astronomical Society of Canada and that he had made welcome visits to Toronto, the last in 1916. The Chairman expressed the thanks of the meeting to Miss Northcott for her excellent address.

Mr. Petersen read a report of a brilliant aurora observed recently in Scotland. Mr. Duncalfe gave a statement relating to the recent approach to the earth of a planetoid which passed at a distance of 400,000 miles, the closest known approach of any planetary body.

Dr. Heard continued his course on introductory studies with a lecture on Spectroscopy, in which he explained refraction, dispersion, continuous and bright-line spectra, spark spectra of ionized atoms, and absorption spectra. The spectra of the sun and practically all stars are absorption spectra proving that they have incandescent cores surrounded by low pressure atmospheres. The study of stellar spectra reveals the constitution, temperatures, motions and other characteristics of the stars and nebulae.

The Chairman announced that the library would be open every Thursday evening until 10 P.M.

March 8, 1938.—The regular meeting of the Toronto Centre was held in the McLennan Laboratory, University of Toronto, on Tuesday, March 8, 1938, at 8 P.M. In the absence of the Chairman, Mr. J. R. Collins presided. Mr. Samuel Butler, 488 Gladstone Avenue, Toronto, was elected to membership in the Society.

The paper of the evening was given by Mr. S. C. Brown, on "Optical Parts and Care of Telescopes." The lecturer, after giving a brief history of the making and uses of optical glasses, proceeded with a detailed discussion of the construction and figuring of various types of optical parts for refracting and reflecting telescopes, ending with a demonstration of the silvering of a small mirror. After brief discussion Mr. Collins expressed the appreciation of the meeting for Mr. Brown's careful and thorough treatment of the subject.

Dr. Heard continued his elementary course of lectures by dealing with "Stellar Motions" and "Binary Systems" in his own clear and interesting way. He pointed out how such studies yield valuable information, for example, as to the direction and velocity of the motion of the solar system, the rotation of the galaxy, the direction and distance of the galactic centre, the sun's period of rotation about the centre, and the total mass of the galaxy. Studies of binary stars furnish knowledge of their properties, as well as methods of measuring quantities not otherwise directly measurable. After brief discussion the meeting adjourned.

D. W. BEST, *Recorder*

AT VANCOUVER

December, 1937.—The 51st regular meeting was held in Science 200, U.B.C., at 8.00 p.m., Mr. H. P. Newton presiding. Minutes of the last meeting were read and adopted. Mr. P. Murphy was elected to membership and the transfer of Dr. T. A. Gorrell from the Victoria Centre was announced. From a choice of subjects for the March meeting "The Origin of the Earth and Planets" was selected. As this was the Annual Meeting, the Secretary's report was read and the Treasurer's report for the year, after audit by Messrs. Thrupp and Stewart, was presented and adopted.

A slate of officers for 1938, nominated by the Council and mailed to members with the meeting notices, was presented and, there being no alternative nominations, was declared elected. (See page 00.)

The half-hour subject was given by Prof. W. H. Gage of the University of B.C. who discussed "The Sun". After enumerating dimensional details and attributing all life and motion in the solar system to the sun, Mr. Gage pointed out that the sun is a star of average size and temperature. With a mass 700 times that of the rest of the solar system and a surface temperature of approximately 6000° the sun radiates energy at a rate equivalent to 1.26×10^{14} horse power. Old theories as to the source of this energy and the present mass-conversion hypothesis were touched upon, and the equator to pole variation of rotation period, also a variation of equatorial rotation with time were described. The sun's motion in the local system and in the galaxy were also described.

Details of the sun's surface layers were presented. Discussion at some length of sunspot activity—the intensity cycle, positional variation of sunspot belts, grouping, magnetic and other observational phenomena on the sun and on the earth—concluded an interesting discourse.

Demonstrations in physics by Dr. Crooker, of the University of B.C., followed, three being presented, viz.—Newton's Rings, Absorption Effects, and Abbe's Diffraction Experiment illustrating image formation.

After a vote of thanks to Prof. Gage and Dr. Crooker, the meeting adjourned.

J. TEASDALE, *Secretary.*

January 11, 1938.—The 52nd regular meeting of the Vancouver Centre branch was held in room 200, Science Building, University of British Columbia,

at 8 p.m., with Mrs. Laura Anderson, the new president, in the chair. The minutes of the last meeting were read and adopted.

The half-hour topic was The Moon, given by the president. Mrs. Anderson gave a very interesting descriptive discourse on her subject, giving a great deal of information in the brief time available. A series of excellent slides illustrated her address.

The president then called on Dr. William Ure, of the U. B. C., to address the meeting, his subject being Stellar Chemistry. With the aid of a periodic chart of the elements, Dr. Ure dwelt at some length on modern views of atomic phenomena, radio-activity, and transmutation, and outlined the part played by spectrum analysis in revealing atomic structure. He then showed that at stellar surface temperatures, only the simpler atomic combinations could exist, while under conditions existing in the interiors of stars (at millions of degrees Centigrade) electrons could be stripped away from their orbits, and even nuclear disintegration could take place.

The Harvard classification of stars was outlined, with colour and spectral characteristics of the main types, surface temperatures, and the evolution of a star from a red giant to a white dwarf briefly described. No elements have been observed in the stars that do not exist on the earth; in the sun, 66 of the elements have been identified. The extreme states in which matter can exist is illustrated by white dwarf stars, where densities millions of times that of water can be accounted for only by assuming that closely packed atomic nuclei make up the stars' mass.

Referring to the internal source of energy of the stars, and to the conversion of matter to energy, Dr. Ure stated that the mass equivalent of the sun's radiation is four million tons per second; that the energy from one pound of matter would melt thirty million tons of rock.

In conclusion, the speaker turned to the earth, where temperature is favourable to the stability of most of the elements and their combination into a vast array of compounds, inorganic and organic, culminating in intelligent life.

After a brief discussion, a vote of thanks was accorded to both speakers, and the meeting adjourned.

February 8, 1938.—The 53rd regular meeting of the Vancouver Centre was held in room 200, Science Building, University of British Columbia, at 8.00 p.m. The meeting was opened by the president. The minutes of the previous meeting were read and adopted.

Mr. A. Outram then gave a very interesting talk (the fifth in the series of 30-minute talks on "The Solar System") on "The Inferior Planets". After pointing out the misconception of relative planetary distances likely to result from the diagrams usually published in books, due to their not being drawn to scale, Mr. Outram discussed the chief physical features of the planets Mercury and Venus and their orbits, especially emphasizing relative sizes and distances

by means of discs cut to scale and by blackboard diagrams. In discussing Venus, the speaker drew special attention to the eccentricity of its orbit, the speed of its motion, and the marked variation in its appearance as seen from the earth,—using cardboard models to make the latter clear to his listeners. He concluded by mentioning instances in times past when the unusual apparent brightness of Venus which occurs at regular long intervals was the cause of unwarranted fear and speculation in the minds of people at various places.

The president then introduced Dr. A. M. Crooker, of the Physics Department of University of British Columbia, who gave an extremely interesting and informative lecture on the subject "Electron Optics".

Dr. Crooker introduced his subject by means of a brief historical outline of the development of our knowledge about the particles which we believe are involved in the structure of the atom. This was accompanied by many interesting demonstrations, involving the conduction of electricity through gases at low pressures, fluorescence, the mechanical effect of a stream on electrons, and the effect of magnetic fields on such a stream and on Lissajou's figures as provided by an oscillograph. This was followed by a summary of our present knowledge (and postulates) regarding the so-called *elemental particles*, and by an introduction to the idea that moving electrons possess the characteristics of waves, whose length can be expressed in terms of a simple formula involving the accelerating voltage of those electrons.

Dr. Crooker then described several devices by which electron streams can be controlled and restrained to paths resembling those of light beams in various optical instruments. These were, first,—an arrangement to cause such a stream of electrons to become divergent,—then, the set-up for an electron-microscope, whose magnification is expressible in terms of voltages applied to the anode and grid respectively, and, finally, the general arrangements for an electron camera. Dr. Crooker pointed out that electron optics have resulted chiefly from research connected with the development of television, and also that the possibility of its application to astronomy is rather remote, due to the fact that local sources and vacua seem necessary for the control of the electrons. The lecturer showed the arrangement for refracting a simple beam of electrons, and pointed out the similarity in form of the formula for expressing the index of refraction under these conditions, as compared with the usual optical formula.

Finally were shown two models (built up of laminated material so that they resembled contour maps) to make clear the relation between equipotential lines and the convergence or divergence of beams of electrons.

After a brief discussion, both speakers were thanked for their contributions, and the meeting adjourned.

H. W. Fowler, *Secretary*.

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